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THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

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THE

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VOLUME XLVI — DECEMBER 1917 — NUMBER 5

A DIFFERENTIAL SPECTRO-PHOTOMETER

By G. A. SHOOK

The novel feature of this spectro-photometer is the differential double slit, shown in Fig. 1. Two slits A and B are actuated by means of a single micrometer M. The lower jaw of the upper slit A and the upper jaw of the lower slit B are rigidly connected by a movable piece C, as shown.

When the micrometer screw is turned clockwise, C moves downward, making A wider and B narrower. When it is turned counterclockwise, the spring S causes C to follow the screw. The sum of the two slit-widths can be varied by means of the capstan screws D. The lower jaw of the lower slit is held in position by means of a spring, so that the slit will not be injured if the screw is turned too far.

In the instrument, as used by the writer, each slit is 1 mm wide when the other is entirely closed; that is, when both slits are equal in width each is 0.5 mm wide. The micrometer-head is divided into 100 divisions and the pitch of the screw is 1 mm, so that when A is open the micrometer reads 100, when closed, 0, and when both slits are equal in width it reads 50.

The method used for bringing the two photometric fields together is shown in Figs. 2 and 3.

The light after passing through the slits A and B is rendered parallel by means of two lenses, as shown in Fig. 3. The upper beam passes directly through a photometric cube C and thence through an ordinary spectrometer prism P. By means of a third lens this beam is brought to a focus at the ocular slit E. The photometric cube is a double prism with a strip of silver on the hypotenuse face of the upper prism. When the eye is placed at E it sees a field divided into three parts, as shown, the outer parts being illuminated by the light from the upper slit.

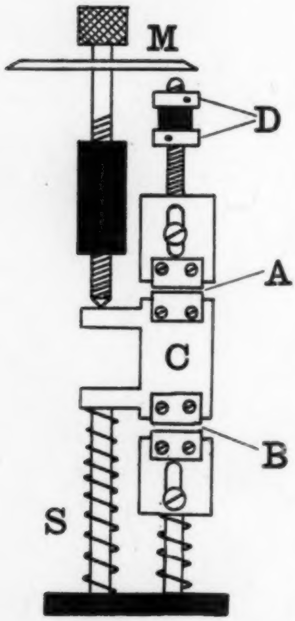


FIG. 1.—The differential slit

The light from B, after passing through the lens, is reflected from D, then from the silver strip S, and finally reaches the ocular slit E. The central part of the field is therefore illuminated by the light from B.

The telescope is rigidly fastened to the support, to which the several prisms are attached and the various wave-lengths are brought into the field by means of a micrometer-screw attached to the ocular slit.

I. AS A SPECTRO-PHOTOMETER

In order to make spectro-photometric measurements with this instrument it is necessary to place a reflecting prism in front of one or both of the slits. The slits are 2 inches apart in the instrument constructed by the writer, but if they were 3 inches or more two sources of light might be compared without the use of reflecting prisms. Due to the fact that the light from B is absorbed more than the light from A (on account of the reflecting prism D, Fig. 3) it is necessary to apply a correction when the intensities of two lights are compared.

The instrument was constructed primarily, however, for obtaining coefficients of reflection and for measuring the concentration of colored solutions, and in these cases the assymetry of the two optical paths is taken care of by the proper adjustment of the light-sources.

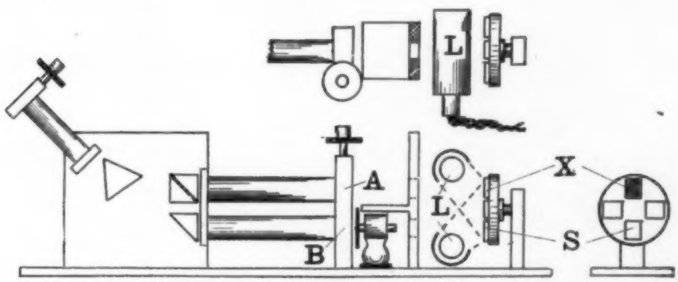


FIG. 2.—The spectro-photometer as used in determining coefficients of reflection

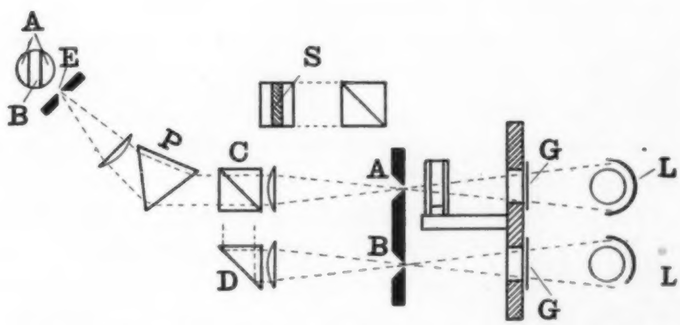


FIG. 3.—The optical system of the differential spectro-photometer

If I_A and I_B are the intensities of two light-sources placed in front of slit A and slit B, respectively, the ratio of the intensities is manifestly given by the following equation,

$$\frac{I_A}{I_B}=\frac{100-R}{R}, \qquad (1)$$

where R is the reading of micrometer.

A few values of this ratio are given in Table I.

TABLE I

Reading of Screw R	Width of A in mm	Width of B in mm	Ratio I_A/I_B
90	0.90	0.10	0.111
80	.80	.20	.250
70	.70	.30	.429
60	.60	.40	.666
50	.50	.50	1.000
40	.40	.60	1.500
30	.30	.70	2.333
20	.20	.80	4.000
10	0.10	0.90	9.000

II. AS A SPECTRO-COLORIMETER

When the instrument is used for colorimetric measurements, the slits are illuminated as indicated in Fig. 3. Two tubular lamps L and L, provided with reflectors, are placed directly in front of the slits and the light is diffused by means of two ground-glasses G and G. The lamps are provided with suitable clamps, so that they may be easily adjusted to produce equality of brightness when the slits have the same width, i.e., when the micrometer reads 50. If a colored liquid is to be examined it is placed in a glass cell, which in turn is placed in front of A. The initial photometric balance in this case is made with the cell in position and filled with the solvent to be used.

Applying Beer's law to equation (1), the concentration C, in terms of the slit-reading R, becomes

$$C = A \log \frac{1}{R}. \tag{2}$$

The *absorption ratio* A is a constant which depends upon the solution in question and the wave-length of light used.

The variation of C with $\log \frac{1}{R}$ is shown in Table II.

The *concentration scale* for this instrument is somewhat more uniform than that of the ordinary form of double-slit spectro-

TABLE II

Reading of Screw R	$\log \frac{1}{R}$	Reading of Screw R	$\log \frac{1}{R}$
80	0.602	60	0.176
75	.477	55	.087
70	.368	50	0.000
65	0.269		

colorimeter or the Koenig-Martens polarization spectro-photometer. The three *concentration-curves* plotted to the same scale are shown in Fig. 4.

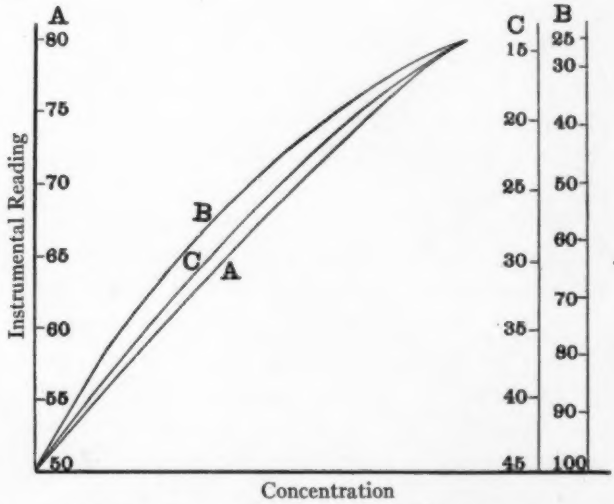


FIG. 4.—Relation between the instrumental reading and the concentration for the differential spectro-photometer A, double-slit spectro-photometer B, polarization spectro-photometer C.

III. AS A PYROMETER

The principle of the differential slit could evidently be adapted to a pyrometer, in which case it might take the form shown in Fig. 5.

Light from the body whose temperature is desired enters A and light from a suitable standard lamp S enters B. The ocular slit E

would in this case be adjusted for a particular wave-length, preferably $0.65\,\mu$.

While the temperature-scale in this case is more uniform than that which obtains for a polarizing instrument (Wanner or Scimatco Pyrometer), the limits of measurement of temperature are not nearly so great, as a slit-width ratio of 1 to 10 could hardly be depended upon.

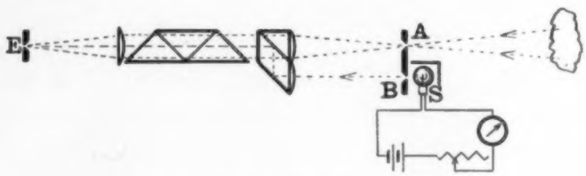


FIG. 5.—Differential-slit pyrometer

Suppose the standard lamp is so adjusted that when the observed temperature is 1000° C. a balance obtains for $R=50$, then applying Wien's law the relation between R and the temperature t is that given in columns 1 and 2 of Table III.

TABLE III

Reading of Screw R	Temperature t C.	Rotation of Analyzer	Temperature t C.
90	860°	9°	775°
80	900	18	855
70	940	27	910
60	970	36	955
50	1000	45	1000
40	1030	54	1050
30	1060	63	1110
20	1110	72	1195
10	1180	81	1350

In a similar manner if the Wanner pyrometer standard lamp is adjusted so that 1000° C. corresponds to 45° of rotation of the Nicol analyzer, the relation between the degrees of rotation and the temperature t is that given in columns 3 and 4 of Table III.

By means of suitable absorption screens several scales could, to be sure, be provided and the instrument might prove a useful pyrometer.

Any pyrometer utilizing a prism for obtaining monochromatic light has clearly certain advantages over an instrument using the so-called "monochromatic red" glass. The question of selective absorption of the absorption screens would not enter in.

IV. DETERMINATION OF COEFFICIENTS OF REFLECTION

Suppose it is desired to determine the percentage of light reflected from a given colored paint or paper in terms of some white standard. The method of procedure is as follows:

The ground-glasses are removed and the colored paint X and the white standard S are placed as shown in Fig. 2. The circular plate upon which these specimens are placed may be rotated about an axis of the instrument and thereby the position of X and S may be easily interchanged. By means of this device any small inequality of illumination of the two surfaces may be eliminated, and therefore it is not necessary to obtain an accurate initial balance.

To make the initial balance, two additional white surfaces are placed on the two remaining quadrants of the plate, as shown. The plate is now rotated until both slits are illuminated by light reflected from the two standard surfaces. With the micrometer set at 50 the two lamps, which are arranged as shown, are adjusted until a balance obtains.

In measurements of this sort it is, of course, necessary to make a number of observations and by means of this rotating plate half of these may be made with the surfaces in one position and half of them with the surfaces interchanged so that only an occasional checking of the initial balance is necessary.

When the unknown surface X is in front of A, the upper slit, the percentage of light reflected from X for a particular wave-length is

$$r_\lambda = \frac{100-R}{R}. \tag{3}$$

When X is in front of B, r_λ becomes

$$r'_\lambda = \frac{R}{100-R}. \tag{4}$$

The true value is the mean, provided that the difference $r_\lambda - r'_\lambda$ is small.

In order to measure small reflection coefficients without narrowing down slit *B* too much a sector disk is used. This disk is rotated by a small motor, which is an integral part of the apparatus (Fig. 2). Several disks were made, but for most purposes one disk with a transmission of 0.2 is sufficient. When not in use, it is only necessary to rotate it until the opening is opposite the slit. The reflection coefficients for several values of *R* are shown in Table IV.

TABLE IV

Reading of Screw *R*	Percentage of Light Reflected (without Disk)	Percentage of Light Reflected (with Disk)	Reading of Screw *R*	Percentage of Light Reflected (without Disk)	Percentage of Light Reflected (with Disk)
70	0.429	0.086	45	....	0.244
65	.538	.108	40	....	.300
60	.666	.133	35	....	.371
55	.818	.164	30	....	0.466
50	1.000	0.200			

It is thus seen that reflection coefficients from 0.1 to 1.0 may be measured without changing the disk and furthermore without using a ratio of slit-width much greater than 1 to 2.

A second motor, not shown in Fig. 2, was provided with a similar disk, so that it could be used in front of slit *A* when the position of the reflecting surfaces were interchanged.

Williams College
Williamstown, Mass.
October 29, 1917

THE LUMINOSITIES AND PARALLAXES OF FIVE HUNDRED STARS[1]

FIRST LIST

By WALTER S. ADAMS and A. H. JOY

The determination by means of a study of their spectra of the luminosities and parallaxes of the stars under investigation for radial velocity at the Mount Wilson Observatory has been continued as a regular part of the stellar spectroscopic work. The methods employed are essentially those described by one of us in a series of papers[2] published somewhat more than a year ago. So far as these methods have been modified or extended in the course of the present investigation, reference will be made accordingly.

Although the observational material and the number of parallax determinations have accumulated rapidly, it has seemed preferable to us to delay the publication of the results until enough were available to make possible a detailed comparison with the trigonometrical parallaxes. Moreover, we have found that the accuracy of the estimation of relative line-intensities depends to a considerable extent upon the number of photographs. A single spectrogram, owing to under- or over-exposure or peculiarities in the plate-grain, will sometimes give an inaccurate value which subsequent plates will correct. Accordingly we have attempted as far as possible to secure at least three photographs of the spectrum of each star.

Another important consideration is the fact that measured parallaxes[3] of a high degree of accuracy are being published at frequent intervals. Since the spectroscopic determinations depend upon empirical curves connecting line-intensity with absolute magnitude, and since this absolute magnitude is calculated from the

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 142.

[2] Adams, *Mount Wilson Communications*, Nos. 23–26; *Proceedings of the National Academy of Sciences*, **2**, 143, 1916.

[3] The term "measured parallaxes" is used in this article to designate those determined trigonometrically. In the absence of a better term "spectroscopic parallax" is also employed. This should not be confused with the radial-velocity method used for parallax determinations in double-star systems, and employed, for example, by Wright in the case of α Centauri.

measured parallax, it is desirable from time to time to readjust the curves with the aid of such new material as is available.

In the list of results for 500 stars which is given in this communication the attempt has been made to include as many stars as possible with measured parallaxes. Since many of the recent values by Mitchell and Miller are for relatively bright stars, we have added to our observing list the stars of the *American Ephemeris* with types between F0 and M. In addition there are included many stars of small proper motion observed by van Maanen. The measured parallaxes of a number of these have been used in the establishment of the relationships between line-intensity and absolute magnitude and have proved of great value. For the most part they are stars of high luminosity and so are particularly useful in fixing the lower portions of the magnitude-curves. A number of the results of Mitchell have been equally valuable in this respect. About 80 stars in all have been used in determining the reduction formulae for the various types.

There are three classes of stars in the list for which modifications have been made of the methods of reduction used previously. These are the early F-type stars and the giants and dwarfs of type M. It was soon found in the case of the F0 to F5 stars that the line λ 4455 of calcium showed but little variation with absolute magnitude. On the other hand, the strontium line at λ 4215 still remained available, and a search was made for additional lines to supplement it. Such lines were found in the similar strontium line at λ 4077, and the line at λ 4290, which probably is due, at least mainly, to enhanced titanium. All three of these lines increase in intensity with increase of luminosity. They are compared in intensity with three neighboring iron lines, λ 4072, λ 4250, and λ 4271, respectively, and the reduction-curves have been formed in the usual way by determining these differences for stars of measured parallax. This method gives satisfactory results for stars with spectra between A8 and F5. For stars later than F5 the usual lines λ 4215 and λ 4455 are employed.

The giant M-type stars have proved most difficult of treatment. The plan finally adopted in their case has been to compare the spectrum of each star with that of α Orionis, which probably is the

most highly luminous star of this type of which we have any certain knowledge, and to estimate the differences in intensity of certain selected lines in their spectra. The lines chosen are λ 4077 of strontium, a line of uncertain origin at λ 4207, λ 4215 of strontium, and the two hydrogen lines $H\delta$ and $H\gamma$. All of these lines increase in intensity with the luminosity of the star. They are nearly as strong in the spectrum of α Scorpii as in that of α Orionis, and this star has served as one of the fundamental points for the reduction curves. Its parallax as determined from group-motion has been furnished to us by the kindness of Professor Russell. Additional points for the reduction-curves are provided by the parallaxes of M-type stars of van Maanen and Mitchell. This method of reduction, though not entirely satisfactory, is the best which we have as yet been able to devise.

The recent determinations of the parallax of the star of large proper motion discovered by Barnard indicate that its absolute magnitude is about 13.3. The reduction-curves previously used for stars of this type depended upon extreme values of about 11.0, and were nearly asymptotic to the magnitude axis at this point. Accordingly it became essential to extend the curves to include fainter stars of this type. The calcium line at λ 4455 reaches so great an intensity in all dwarf M-type stars that it becomes difficult to make use of it for the determination of relatively small differences. An examination, however, of the low-temperature line of strontium at λ 4607 showed a marked increase of intensity in the spectrum of Barnard's star as compared with other stars of this class, and the character of the line is such as to make estimates of its intensity comparatively simple. We have therefore used this line in determining the relative absolute magnitudes of the various dwarf M stars. It is worthy of note that in the case of both classes of M-type stars the modifications introduced into the reduction method have been for the purpose of securing more accurate determinations of magnitude within each class. They may therefore be regarded as an attempt at a second approximation, with the separation into the two classes as the first.

The results of our determinations are given in Table I. The values for spectral types and absolute magnitude are the means of

TABLE I

No.	Name	Harv. Visual Mag.	Harv. Spec.	α 1900	δ 1900	μ	No. Pl.	Spectrum Est.	Spectrum Meas.	Abs. Visual Mag.	Lum.	π	Trig. π	Auth.
1	Lal. 47231[1]	8.9	K2	$0^h\ 0^m.4$	+45° 16′	0″.90	4	K7	K7	+9.3	0.019	0″.120	+0″.096	Y, S, Fox
2	Σ 3062 Br	6.9	F	0 1.0	+57 53	0.266	3	G4	G2	+5.2	0.832	0.046	+0.036	Mil.
3	Σ 3062 Ft	8.0	.....	0 1.0	+57 53	0.266	2	G9	G8	+5.3	0.759	0.029		
4	12 Ceti	6.0	K	0 24.9	− 4 31	0.011	3	K5	K2	+1.7	20.9	0.014	.....	.....
5	Boss 96	5.7	G5	0 26.2	+52 17	0.056	3	K0	K0	+0.3	75.9	0.008	+0.008	vM
6	Boss 106	6.4	G5	0 27.5	+27 44	0.014	3	G6	G7	+0.4	69.2	0.006	+0.005	vM
7	Pi. 0h130	5.7	K	0 32.2	−25 19	1.39	3	G8	G6	+4.8	1.20	0.066	.....	.....
8	ε Androm	4.5	G5	0 33.3	+28 46	0.336	3	G3	G4	+1.3	30.2	0.023	+0.075	S and M, Mil.
9	δ Androm	3.5	K0	0 34.0	+30 19	0.162	2	K3	K3	+1.4	27.5	0.038	.....	.....
10	Lal. 999	7.4	G	0 34.0	+ 2 35	0.79	3	G3	G1	+5.2	0.832	0.036	+0.033	Y, Jw.
11	α Cassiop	{2.2, 2.8–}	K0	0 34.8	+55 59	0.060	2	G8	G8	−0.9	229.	{0.018–, 0.024}	+0.023	F, M
12	Lal. 1045	7.5	K	0 35.3	+39 39	0.81	3	K3	K3	+5.8	0.479	0.046	+0.017	Y
13	η Cassiop. Br	3.6	F8	0 43.0	+57 17	1.242	3	F9	G0	+5.0	1.00	0.190	+0.191	5
14	η Cassiop. Ft	7.6	.....	0 43.0	+57 17	1.242	1	K4	K0	+8.7	0.033	0.166	.....	.....
15	Groom. 145	8.0	K	0 43.3	+69 54	0.54	3	K2	K2	+6.2	0.331	0.044	+0.028	Y
16	A. G. Hels 914	8.7	.....	1 0.3	+63 24	1.62	2	K7	K6	+8.6	0.036	0.096	.....	.....
17	Lal. 1966	7.9	F5	1 3.3	+61 1	0.69	3	F5	F5	+5.1	0.912	0.028	+0.022	Y, S and M
18	β Androm	2.4	Ma	1 4.1	+35 5	0.216	2	Ma	G8	+1.6	22.9	0.069	+0.058	F, M
19	W.B. 1h161	8.0	K	1 13.5	− 1 23	0.54	5	K0	G9	+6.1	0.363	0.042	−0.011	Y
20	Lal. 2387	8.5	G	1 14.0	− 9 27	0.57	2	G1	G1	+4.7	1.32	0.017	+0.026	Y
21	Lal. 2450	8.1	F8	1 16.9	+18 10	0.57	3	G0	G1	+5.7	0.525	0.033	+0.017	Y
22	ω Androm	5.0	F5	1 21.7	+44 53	0.356	1	F0	F1	+3.4	4.37	0.048	+0.037	F, Jw., M
23	α Urs. Min	2.1	F8	1 22.6	+88 46	0.044	8	F8	F8	+0.6	57.5	0.050	+0.041	10
24	Lal. 2682	7.8	G5	1 23.6	+21 13	0.53	6	K3	K2	+6.5	0.251	0.055	+0.009	Y
25	η Piscium	3.7	G5	1 26.1	+14 50	0.031	2	G5	G5	+0.3	75.9	0.021	+0.056	M
26	40 Cassiop	5.5	K	1 30.5	+72 32	0.008	3	G6	G5	+0.2	83.2	0.009	.....	.....
27	υ Androm	4.2	G0	1 30.9	+40 54	0.418	2	F9	F9	+4.0	2.51	0.091	+0.057	M
28	Lal. 2966	7.6	G5	1 34.2	+66 25	0.76	3	G4	G2	+6.2	0.331	0.052	+0.036	Y
29	Lal. 3128	5.3	G8	1 37.1	+19 47	0.718	4	K1	K1	+5.5	0.631	0.110	+0.129	Y
30	τ Ceti	3.6	K0	1 39.4	−16 28	1.922	3	G7	G5	+6.2	0.331	0.331	+0.317	4
31	Boss 405	5.8	F	1 43.0	+32 11	0.354	3	F6	F8	+3.9	2.75	0.042	.....	.....
32	Boss 420	5.6	K	1 47.3	+40 14	0.009	3	K2	K1	+0.6	57.5	0.010	+0.006	vM
33	Lal. 3922	7.5	G	2 2.5	− 1 5	0.50	3	F9	G0	+3.8	3.02	0.018	−0.042	Y
34	55 Cassiop	6.2	F5	2 6.6	+66 3	0.003	3	F5	F7	+1.9	17.4	0.014	.....	.....
35	6 Persei	5.4	K0	2 7.0	+50 36	0.386	1	G6	G3	−0.3	132.	0.008	−0.001	L and J
36	Lal. 3987	7.8	K	2 7.5	+67 13	0.56	3	K2	K2	+6.0	0.398	0.044	+0.097	Y
37	W.B. 2h95	8.3	G	2 9.5	− 1 40	0.97	5	F8	F9	+4.4	1.74	0.017	+0.014	Y
38	Lal. 4141	6.9	G	2 9.7	+23 49	0.60	4	G7	G4	+4.5	1.58	0.033	+0.029	Y
39	Lal. 4268	5.8	F5	2 12.8	+ 1 17	0.527	3	F7	F8	+4.0	2.51	0.044	.....	.....

40	Boss 556	6.5	G	2 22.1	+ 9 45	0.355	4	F5	F6	+4.5	1.58	0.040	....	....
41	Boss 592	7.4	F	2 31.2	+24 13	0.152	3	F5	F7	+3.7	3.31	0.018	+0.010	vM
42	Boss 593	6.6	F5	2 31.2	+24 13	0.140	6	F3	F5	+3.9	2.75	0.028	+0.030	vM
43	Lal. 4855	7.2	G	2 32.6	+30 24	0.60	3	F8	F8	+4.7	1.32	0.032	+0.026	Y, F
44	θ Persei	4.2	Go	2 37.4	+48 48	0.351	3	F7	F7	+4.2	2.09	0.100	+0.088	S
45	SU Cassiop.	{5.9– 6.3}	F	2 43.0	+68 28	0.016	7	F5	F5	+1.0	39.8	0.010	+0.010	vM
46	η Persei	3.9	Ko	2 43.4	+55 29	0.030	2	K3	G4	+0.5	63.1	0.021	....	....
47	τ Persei	4.1	Gop	2 47.2	+52 21	0.008	2	G1	G1	+1.5	25.1	0.030	....	....
48	20 Persei	5.3	F	2 47.4	+37 56	0.099	4	Fo	F2	+3.3	4.79	0.040	+0.013	S and M, Mil.
49	Boss 672	5.6	G5p	2 53.0	+46 49	0.035	3	G3	G3	+1.5	25.1	0.015	−0.007	vM
50	α Ceti	2.8	Ma	2 57.1	+ 3 42	0.078	2	Ma	G8	+0.5	63.1	0.035	+0.022	M
51	ρ Persei	{3.4– 4.2}	Mb	2 58.9	+38 27	0.173	2	Mb	G7	−0.5	158.	{0.011– 0.017}	+0.047	R, M
52	ι Persei	4.2	G	3 1.8	+49 14	1.269	3	Go	Go	+4.1	2.29	0.096	+0.126	4
53	δ Arietis	4.5	Ko	3 5.9	+19 21	0.152	2	Ko	G9	+1.0	39.8	0.020	....	....
54	α Persei	1.9	F5	3 17.2	+49 30	0.039	3	F5	F7	+0.3	75.9	0.048	+0.016	F, S and M
55	Lal. 6320	7.9	K5	3 20.1	− 5 42	0.86	3	K5	K5	+7.1	0.145	0.069	+0.062	Y, M, Jw.
56	ε Eridani	3.8	K	3 28.2	− 9 48	0.972	4	K2	K1	+6.1	0.363	0.288	+0.317	Y, F, M
57	10 Tauri	4.4	G5	3 31.8	+ 0 5	0.536	4	F8	F9	+3.8	3.02	0.076	+0.074	Y, Jw.
58	Boss 831	5.9	A	3 34.1	− 5 57	0.204	2	Ko	Ko	+3.2	5.25	0.029	....	....
59	W.B. 3h617	7.2	F8	3 35.3	− 3 32	0.79	3	F6	F7	+4.6	1.45	0.030	−0.073	Y
60	ν Persei	3.9	F5	3 38.4	+42 16	0.009	2	F5	F6	+0.7	52.5	0.023	....	....
61	δ Eridani	3.7	K	3 38.4	−10 6	0.749	3	G9	G9	+2.9	6.92	0.069	+0.147	Y, F, M
62	B.D. +23°535	7.9	....	3 41.4	+23 25	....	3	F5	F5	+3.9	2.75	0.016	+0.007	Y
63	γ Eridani	3.2	K5	3 53.4	−13 48	0.130	2	K6	Ko	+1.5	25.1	0.046	....	....
64	Lal. 7443	8.6	G	3 56.5	+35 2	2.19	3	Ko	G8	+6.7	0.209	0.042	+0.040	6
65	Boss 933	5.7	Comp.	3 58.4	+23 50	0.022	3	F5p	F7	+1.4	27.5	0.014	+0.014	vM
66	A Tauri	4.5	Ko	3 58.8	+21 49	0.113	2	Ko	G9	+1.1	36.3	0.021	....	....
67	43 Tauri	5.7	G	4 3.3	+19 21	0.114	2	K1	Ko	+1.8	19.1	0.017	+0.024	M
68	o² Eridani	4.5	G2	4 10.7	− 7 49	4.085	4	K1	Ko	+6.0	0.398	0.200	+0.182	4
69	γ Tauri	3.9	Ko	4 14.1	+15 23	0.120	3	G7	G8	+0.1	91.2	0.017	....	....
70	Boss 1014	6.1	K	4 16.4	+20 35	0.011	3	Ma	G5	+0.5	63.1	0.008	+0.001	vM
71	δ Tauri	3.9	Ko	4 17.1	+17 18	0.115	2	G8	G9	+0.8	47.9	0.024	....	....
72	ε Tauri	3.6	Ko	4 22.8	+18 58	0.120	4	G9	G9	0.0	100.	0.019	....	....
73	θ¹ Tauri	4.0	Ko	4 22.9	+15 44	0.108	3	G9	G8	+0.9	43.7	0.024	....	....
74	A. Oe. 4961	8.5	....	4 29.9	+52 42	0.48	4	K6	K5	+8.6	0.036	0.105	+0.099	S and M
75	α Tauri	1.1	K5	4 30.2	+16 18	0.201	6	K5	K2	+0.9	43.7	0.091	+0.070	5
76	Groom. 864	7.3	G	4 34.5	+41 56	0.73	2	G2	G1	+6.1	0.363	0.058	+0.028	Y, F
77	Boss 1128	5.8	Mb	4 42.7	+63 20	0.111	4	Mb	Ko	+2.2	13.2	0.019	....	....
78	Boss 1131	6.8	G5	4 42.8	+18 33	0.440	6	F9	Go	+4.9	1.10	0.042	....	....
79	π³ Orionis	3.3	F8	4 44.4	+ 6 47	0.471	2	F5	F6	+4.4	1.74	0.166	+0.156	M
80	Lal. 9091	7.0	F5	4 45.7	+10 54	0.10	3	F9	F8	+4.6	1.45	0.033	+0.007	F, Mil.
81	Lal. 9109	6.7	F5	4 46.2	+13 29	0.13	3	F7	F6	+3.9	2.75	0.027	+0.007	F
82	ι Aurigae	2.9	K2	4 50.5	+33 0	0.028	2	K3	Ko	−0.1	110.	0.025	−0.011	F
83	A. G. Leid. 1812	8.0	....	4 51.3	+34 7	0.76	3	G9	G7	+7.7	0.083	0.087	....	....
84	β Camelop	4.2	Go	4 54.5	+60 18	0.013	2	F7p	F8	−0.9	229.	0.010	....	....

TABLE I—*Continued*

No.	Name	Harv. Visual Mag.	Harv. Spec.	α 1900	δ 1900	μ	No. Pl.	Spectrum Est.	Spectrum Meas.	Abs. Visual Mag.	Lum.	π	Trig. π	Auth.
85	ε Aurigae	{3.0– 4.5}	F5p	4h 54m.8	+43° 41′	0″.014	2	F5p	F7	−0.3	132.	{0″.011– 0.022}	+0″.060	Jw.
86	ζ Aurigae	3.9	K0p	4 55.5	+40 56	0.032	2	G8	G1	+1.1	36.3	0.027	−0.028	Ab.
87	ε Leporis	3.3	K5	5 1.2	−22 30	0.072	2	K4	K1	+1.6	22.9	0.046	....	....
88	Boss 1217	6.3	G	5 2.3	+ 9 21	0.381	3	G0	G0	+5.0	1.00	0.055	....	....
89	α Aurigae	0.2	G0	5 9.3	+45 54	0.437	4	G1	G0	+0.3	75.9	0.105	+0.075	F, Y, Jw.
90	λ Aurigae	4.8	G0	5 12.1	+40 1	0.846	2	G3	G2	+4.8	1.20	0.100	+0.089	S
91	Lal. 9960	8.5	K	5 14.1	− 3 11	0.73	3	K5	K4	+6.8	0.191	0.046	+0.074	Y
92	17 Camelop	5.8	Ma	5 20.7	+62 59	0.005	3	Ma	G8	+1.3	30.2	0.013	....	....
93	β Leporis	3.0	G0	5 24.0	−20 50	0.094	2	G1	G1	+1.1	36.3	0.042	....	....
94	Groom. 966	6.4	K5	5 26.3	+74 59	0.019	3	Ma	G8	+1.7	20.9	0.012	....	....
95	W.B. 5h592	8.9	Ma	5 26.4	− 3 42	2.23	5	Ma	Ma	+9.9	0.011	0.158	+0.176	F, Sc., Jw.
96	α Leporis	2.7	F0	5 28.3	−17 54	0.003	2	F4p	F5	+0.4	69.2	0.035	+0.014	M
97	Groom. 990	8.1	K	5 30.4	+51 23	0.56	3	K2	K0	+6.0	0.398	0.038	+0.028	Y
98	φ² Orionis	4.4	K	5 31.4	+ 9 14	0.321	3	G7	G6	+1.3	30.2	0.024	+0.024	S and M, Mil.
99	γ Leporis Ft	6.4	K	5 40.3	−22 27	0.461	1	K5	K3	+7.5	0.100	0.166	+0.145	M
100	γ Leporis Br	3.8	F8	5 40.3	−22 29	0.468	2	F7	F7	+4.7	1.32	0.151	+0.108	M
101	δ Leporis	3.9	K0	5 47.0	−20 53	0.696	2	G7	G6	+1.1	36.3	0.027	....	....
102	δ Aurigae	3.9	K0	5 51.3	+54 17	0.153	3	G7	G8	+0.7	52.5	0.023	+0.025	Ab., M
103	η Leporis	3.8	F5	5 51.9	−14 11	0.138	2	F3	F3	+2.1	14.5	0.046	....	....
104	A.G. Ber. 1866	9.0	....	5 57.2	+19 23	0.76	3	F9	G0	+5.2	0.832	0.017	....	....
105	1 Gemin	4.3	G5	5 58.0	+23 16	0.108	2	G3	G3	+2.9	6.92	0.052	....	....
106	Boss 1549	6.1	K	6 6.3	+22 56	0.027	4	Ma	G4	+0.7	52.5	0.008	+0.003	vM
107	η Gemin	{3.2– 4.2}	Ma	6 8.8	+22 32	0.065	2	Ma	G6	+1.7	20.9	{0.032– 0.050}	+0.005	R, M
108	W.B. 6h128	8.4	G	6 9.5	+44 45	0.413	3	G8	G8	+8.0	0.063	0.083	+0.102	Ram.
109	ψ¹ Aurigae	5.1	K2	6 17.2	+49 20	0.014	2	K3	G5p	+1.1	36.3	0.016	....	....
110	Boss 1627	6.0	G	6 22.1	+58 14	0.33	5	G9	G7	+1.6	22.9	0.013	−0.006	Ab.
111	23 Hev. Cam	5.6	F8	6 29.2	+79 40	0.637	3	F8	F7	+4.6	1.45	0.063	+0.037	Y
112	ε Gemin	3.2	G5	6 37.8	+25 14	0.020	2	G8	G2	−1.0	251.	0.014	....	....
113	ψ⁵ Aurigae	5.3	G0	6 39.5	+43 41	0.158	2	F8	F8	+4.0	2.51	0.055	+0.078	Jo.
114	ξ Gemin	3.4	F5	6 39.7	+13 0	0.231	2	F4	F4	+1.0	39.8	0.033	+0.042	M
115	Lal. 13284	6.9	K	6 47.4	− 5 3	0.57	5	K5	K4	+7.2	0.132	0.115	+0.121	Y
116	A.G. Bonn 5621	8.3	....	6 49.5	+40 13	0.57	3	K4	K3	+7.1	0.145	0.058	....	....
117	θ Can. Maj	4.2	K2	6 49.5	−11 55	0.138	2	K4	K1	+1.5	25.1	0.029	+0.017	L and J
118	W.B. 6h1500	7.7	G	6 51.4	+ 1 18	0.57	3	G6	G3	+6.0	0.398	0.046	+0.006	Y
119	ζ Gemin	{3.7– 4.3}	G0	6 58.2	+20 43	0.009	2	F8p	G0	+0.5	63.1	{0.017– 0.023}	+0.025	Ab., Mil.
120	Lal. 13849	6.5	G5	7 4.2	+21 25	0.52	3	K0	G7	+4.0	2.51	0.032	+0.052	Y, Mil.
121	Boss 1868	5.9	K	7 9.7	+28 4	0.020	3	Ma	K2	+0.8	47.9	0.010	+0.008	vM

122	Lal. 14146	7.3	G	7 11.3	−12 53	0.55	3	F8	F9	+5.9	0.437	0.052	+0.080	Y
123	ι Gemin.	3.9	K0	7 19.5	+28 0	0.145	2	G9	G8	+0.8	47.9	0.024	+0.013	M
124	Boss 1971	5.6	G5	7 26.0	+17 18	0.089	3	K1	K1	+0.6	57.5	0.010	0.000	vM
125	Comp. α Gemin	9.0		7 28.2	+32 6		3	K9p		+9.0	0.025	0.100		
126	α Can. Min	0.5	F5	7 34.1	+ 5 29	1.242	6	F3	F4	+3.1	5.75	0.331	+0.309	5
127	Boss 2020	5.8	Ma	7 36.4	+14 27	0.015	3	Mb	G5	+0.4	69.2	0.008	+0.006	vM
128	γ Monoc.	4.1	K	7 36.5	− 9 19	0.079	2	G9	G9	+0.7	52.5	0.021	+0.005	M
129	σ Gemin	4.3	K	7 37.1	+29 8	0.247	1	G9	G7	+1.1	36.3	0.023	+0.030	Jo., L and J
130	W.B. 7h1029	6.8		7 38.2	+39 49	0.52	3	F6	F7	+4.6	1.45	0.036		
131	β Gemin	1.2	K0	7 39.2	+28 16	0.623	4	G9	G8	+0.8	47.9	0.083	+0.064	Y
132	28 Hev. Cam	6.5	G5	7 39.8	+80 31	0.50	3	K0	G5	+4.2	2.09	0.035	+0.049	Y, Gr.
133	Lal. 15290	8.2	G	7 47.2	+30 55	1.97	3	F7	F8	+5.9	0.437	0.035	+0.045	4
134	Lal. 15394	8.2		7 49.1	+19 31	0.50	4	K3	K3	+6.4	0.275	0.044		
135	Boss 2098	6.0	K	7 51.3	+16 3	0.056	3	K3	K2	+1.4	27.5	0.012		
136	Lal. 15547	8.6	F8	7 53.7	+21 8	0.59	3	G9	K0	+5.9	0.437	0.029	+0.089	Y
137	ω Cancri	5.9	K	7 54.9	+25 40	0.014	3	G9	G7	−0.2	120.	0.006		
138	Boss 2148	6.4	K5	8 2.5	+42 43	0.073	4	K4	K2	+1.3	30.20	0.009	−0.030	Ab.
139	3 H. Urs. Maj	5.5	G5	8 2.9	+68 46	0.006	3	G5	G4	+0.2	83.2	0.009		
140	ζ Cancri Br	5.2	G0	8 6.5	+17 57	0.155	2	F8	F9	+3.4	4.37	0.044	+0.031	Mil., F
141	ζ Cancri Ft	6.0		8 6.5	+17 57	0.155	2	G0	G0	+4.1	2.29	0.042	+0.035	Mil., F
142	β Cancri	3.8	K2	8 11.1	+ 9 30	0.075	2	K3	K1	+1.1	36.3	0.029	0.000	M
143	W.B. 8h181	8.6	K	8 12.0	+30 56	0.90	3	K6	K6	+7.0	0.158	0.048	+0.014	Y, F
144	Boss 2236	6.3	F5	8 20.6	+45 59	0.362	3	G4	G0	+4.3	1.91	0.040		
145	Groom. 1450	6.0	K0	8 26.4	+38 22	0.204	2	K2	K1	+1.3	30.2	0.011		
146	32 Lyncis	6.1	F	8 26.9	+36 47	0.139	3	F3	F4	+4.5	1.58	0.048	+0.088	Jo.
147	Boss 2275	6.4	G	8 27.1	+24 25	0.091	3	G9	G7	+0.3	75.9	0.006		
148	A.G. Cam. 3181	8.6		8 28.2	+54 4	0.93	3	G7	G7	+2.1	14.5	0.005		
149	W.B. 8h596	8.6		8 28.8	+42 6	0.76	3	K4	K2	+6.7	0.209	0.042	+0.023	S and M
150	Lal. 16904	8.1	G5	8 33.1	+56 2	0.44	3	G3	G2	+6.4	0.275	0.046	−0.042	Y
151	Lal. 17161	8.4	G	8 38.6	+42 3	0.69	3	K3	K3	+7.2	0.132	0.058	−0.073	Y
152	δ Cancri	4.2	K0	8 39.0	+18 31	0.240	2	K0	G9	+1.0	39.8	0.023	+0.053	M
153	Boss 2338	6.1	G	8 39.2	+31 4	0.020	3	G3	G3	+0.8	47.9	0.008	+0.007	vM
154	ε Hydrae Br	3.5	F8	8 41.5	+ 6 47	0.196	5	F9	G0	+2.5	10.0	0.063 }	+0.004	Mil.
155	ε Hydrae Ft	7.5		8 41.5	+ 6 47	0.196	3	F4	F6	+3.6	3.63	0.016 }		
156	Fed. 1384[1]	9.2	K2	8 46.0	+71 11	1.40	3	K8	K6	+9.7	0.013	0.126	+0.086	F, Gr.
157	Fed. 1384[2]	9.2		8 46.0	+71 11	1.38	1	K7	K5	+9.2	0.021	0.100	+0.086	F, Gr.
158	Boss 2410	6.6	Ma	8 53.5	+18 31	0.089	3	Mc	G8	+1.6	22.9	0.010		
159	10 Urs. Maj	4.1	F	8 54.2	+42 11	0.504	4	F4	F5	+4.4	1.74	0.115	+0.062	F, Y, Mil.
160	81 π[1] Cancri	6.4	G	9 6.8	+15 24	0.576	4	G8	G6	+4.9	1.10	0.050	−0.008	Y
161	Lal. 18115[1]	7.9	K5	9 7.6	+53 7	1.69	3	K8	K7	+8.6	0.036	0.138	+0.152	5
162	Lal. 18115[2]	7.9		9 7.6	+53 7	1.69	3	K8	K5	+9.2	0.021	0.182	+0.152	5
163	Lal. 18286	7.3	K5	9 12.0	+29 0	0.52	3	K3	K4	+6.9	0.174	0.083	+0.067	Y, F, Mil.
164	83 Cancri	6.6	F5	9 13.4	+18 8	0.180	2	F6	F7	+4.9	1.10	0.046		
165	Boss 2528	6.3	G5	9 20.0	+17 1	0.079	3	K0	G9	+1.1	36.3	0.009	+0.015	vM
166	Lal. 18672	7.7		9 24.7	+ 6 5	0.54	3	K4	K3	+5.9	0.437	0.044		
167	d Urs. Maj	4.6	G0	9 25.6	+70 16	0.090	1	G3	G2	+2.7	8.32	0.042	+0.048	Y
168	θ Urs. Maj	3.3	F8	9 26.2	+52 8	1.092	3	F5	F5	+3.5	3.98	0.110	+0.098	4

TABLE I—*Continued*

No.	Name	Harv. Visual Mag.	Harv. Spec.	α 1900	δ 1900	μ	No. Pl.	Spectrum		Abs. Visual Mag.	Lum.	π	Trig. π	Auth.
								Est.	Meas.					
169	11 Leo. Min	5.5	K	9h29m.7	+36° 16′	0″.745	3	K1	G6	+ 4.4	1.74	0″.060	+0″.179	Y, Jo., Mil.
170	o Leonis	3.8	F5p	9 35.8	+10 21	0.150	2	F4p	F5	+ 1.3	30.2	0.032	+0.034	M
171	Boss 2603	6.4	K	9 35.9	+26 22	0.049	2	K1	G8	+ 0.6	57.5	0.007	+0.012	vM
172	W.B. 9h954	9.3	....	9 46.2	−11 49	1.95	1	K8	....	+ 9.7	0.013	0.120	....	....
173	Groom. 1596	8.2	G5	9 54.9	+56 5	0.49	3	G5	G5	+ 5.6	0.575	0.030	+0.069	Y
174	Comp. α Leonis	7.6	G	10 3.0	+12 27	0.247	3	K2	K0	+ 6.0	0.398	0.048	....	....
175	Lal. 19780	7.5	G	10 3.3	−19 15	0.38	3	G2	G0	+ 5.3	0.759	0.036	+0.057	F
176	Lal. 19821	8.5	G5	10 6.3	+24 15	0.42	3	G2	G1	+ 5.0	1.00	0.020	+0.049	Y
177	A.Oe. 10640	9.2	....	10 7.5	+53 1	0.70	1	K5	K4	+ 8.1	0.057	0.060	+0.074	L and J
178	Lal. 19896	7.7	G5	10 8.9	+ 3 39	0.47	3	G0	G0	+ 5.4	0.692	0.035	−0.048	Y
179	39 Leonis	5.8	F5	10 11.7	+23 36	0.44	4	F5	F6	+ 4.6	1.45	0.057	+0.092	Y
180	Munich II 5178	8.8	....	10 15.7	− 0 58	0.70	2	K5	K4	+ 7.8	0.076	0.063	....	....
181	Brad. 1433	5.9	G	10 16.2	+41 44	0.194	3	F7	F8	+ 3.6	3.63	0.035	+0.090	Jo., Mil.
182	μ Urs. Maj	3.2	K5	10 16.4	+42 0	0.084	2	K5	G8	+ 1.8	19.1	0.052	+0.051	Y
183	Groom. 1646	6.5	F8	10 21.9	+49 19	0.898	4	G1	G1	+ 6.1	0.363	0.083	+0.078	K, R, F
184	Pi. 10h96	7.6	F8	10 27.7	+49 42	0.30	3	F6	F6	+ 5.4	0.692	0.036	+0.045	K
185	W.B. 10h520	5.7	F	10 31.6	−11 42	0.734	3	F6	F6	+ 4.4	1.74	0.055	+0.001	Y, F
186	38 Leo. Min	5.8	K	10 33.4	+38 26	0.227	7	F9	F8	+ 2.8	7.59	0.025	+0.029	Ab.
187	B.D. +47°1806	(9.0)	....	10 38.1	+46 49	....	2	F8	F8	+ 4.1	2.29	0.010	....	....
188	Lal. 20670	7.7	G5	10 38.1	+46 44	0.280	7	F9	G0	+ 4.6	1.45	0.024	−0.004	K
189	Boss 2881	6.3	K	10 43.4	+29 57	0.103	3	K0	G9	+ 1.1	36.3	0.009	+0.036	vM
190	Groom. 1697	6.1	K	10 46.7	+70 23	0.403	3	K1	K1	+ 2.9	6.92	0.023	−0.011	Y
191	46 Leo. Min	3.7	K0	10 47.7	+34 45	0.304	4	K1	G9	+ 1.1	36.3	0.030	+0.092	Ab.
192	Boss 2910	5.9	K	10 50.2	+34 2	0.113	3	K0	G9	+ 0.5	63.1	0.008	+0.014	Ab.
193	Lal. 21008	8.5	G	10 50.9	+28 17	0.50	3	G5	G5	+ 5.2	0.832	0.022	+0.050	Y
194	Boss 2921	6.2	Ma	10 54.0	+36 38	0.095	3	Ma	G9	+ 3.6	3.63	0.030	+0.079	vM
195	Lal. 21185	7.6	Ma	10 57.9	+36 38	4.77	3	Ma	K8	+10.8	0.005	0.437	+0.422	7
196	χ Leonis	4.7	F0	10 59.9	+ 7 53	0.350	2	F4	F5	+ 0.1	91.2	0.012	+0.015	M
197	51 Leo. Min	7.5	G	10 59.9	+25 45	0.409	3	F5	F6	+ 4.6	1.45	0.026	+0.039	Y
198	Lal. 21258	8.9	Ma	11 0.5	+44 2	4.47	3	Ma	Ma	+11.2	0.003	0.288	+0.203	5
199	ψ Urs. Maj	3.2	K0	11 4.0	+45 2	0.069	2	G9	G9	+ 1.6	22.9	0.048	....	....
200	Lal. 21368	8.9	K5	11 5.6	+31 0	0.58	3	K6	K4	+ 8.2	0.052	0.072	+0.048	Y
201	Fed. 1831 Br	7.7	K5	11 8.7	+74 1	0.45	3	K5	K5	+ 7.0	0.158	0.072	+0.088	Bg., F
202	Groom. 1757	6.0	K	11 11.1	+50 1	0.092	4	K0	G9	+ 1.6	22.9	0.013	−0.081	Y
203	Boss 2983	5.4	Mb	11 12.1	+ 2 34	0.159	3	Ma	K2	+ 2.8	7.59	0.030	....	....
204	ξ Urs. Maj. Br	4.0	G	11 12.9	+32 6	0.732	3	F9	F9	+ 5.0	1.00	0.158 }	+0.158	Y, Ab., F
205	ξ Urs. Maj. Ft	4.9	....	11 12.9	+32 6	0.732	2	G1	G1	+ 5.6	0.575	0.138 }		
206	Lal. 21565	7.2	K	11 13.2	− 4 31	0.79	5	G8	G5	+ 6.1	0.363	0.060	+0.006	Y
207	δ Crateris	3.8	K0	11 14.3	−14 14	0.230	2	G8	G7	+ 0.3	75.9	0.020	....	....
208	A.Oe. 11677	9.2	....	11 14.8	+66 23	3.03	3	Ma	K8	+10.9	0.004	0.219	+0.198	Bg.

209	83 Leonis Br	6.5	K	11 21.7	+ 3 33	0.743	3	G9	G7	+ 4.9	1.10	0.048	+0.023	Y, R
210	83 Leonis Ft	7.6	....	11 21.7	+ 3 33	0.736	3	K4	K5	+ 6.3	0.302	0.055	+0.023	Y, R
211	Boss 3025	6.0	K	11 24.5	+15 58	0.066	3	K3	K2	+ 1.5	25.1	0.013	....	....
212	Boss 3030	5.7	K	11 25.3	+18 58	0.078	3	K0	G8	+ 0.7	52.5	0.010	+0.024	vM
213	Boss 3032	6.2	G	11 26.6	+14 55	0.387	4	F9	F9	+ 4.9	1.10	0.055	....	....
214	Groom. 1812	6.3	F	11 33.5	+45 40	0.583	2	F9	F9	+ 3.7	3.31	0.030	+0.038	K
215	Boss 3078	5.7	F	11 36.4	+32 18	0.347	3	F2	F3	+ 3.9	2.75	0.044	+0.042	vM
216	Groom. 1822	7.9	G	11 40.3	+48 14	0.66	3	F9	F9	+ 4.4	1.74	0.020	+0.024	K
217	Boss 3089	4.2	Ma	11 40.7	+ 7 5	0.188	3	Ma	G6	+ 1.9	17.4	0.035	....	....
218	93 Leonis	4.5	F8	11 42.8	+20 46	0.155	2	F5p	F7	+ 2.9	6.92	0.048	+0.024	M
219	β Virginis	3.8	F8	11 45.5	+ 2 20	0.793	2	F8	F8	+ 3.8	3.02	0.100	+0.116	Y, M
220	Groom. 1830	6.5	G5	11 47.2	+38 26	7.037	4	G9	G5	+ 6.0	0.398	0.079	+0.102	6
221	Lal. 22585	5.6	G	11 55.6	− 9 53	0.491	5	G9	G7	+ 4.2	2.09	0.052	+0.118	Y
222	Pi. 11h218	6.8	K	11 57.4	+43 39	0.67	3	G9	G6	+ 3.5	3.98	0.022	+0.017	K, F
223	Lal. 22701	8.4	G	12 0.2	− 0 57	0.51	3	G9	G6	+ 8.1	0.057	0.087	+0.110	Y
224	Boss 3169	6.1	K	12 4.6	+ 2 28	0.190	4	K2	K1	+ 1.8	19.1	0.014	....	....
225	W.B. 12h69	7.3	G	12 7.4	− 2 32	0.73	3	G4	G2	+ 4.4	1.74	0.026	+0.011	Y, F
226	Lal. 22954	6.1	F5	12 10.0	− 9 44	1.03	3	F3	F4	+ 4.7	1.32	0.052	+0.026	Y, F
227	Boss 3233	6.1	K	12 20.2	+24 29	0.072	3	G9	G9	+ 0.5	63.1	0.008	+0.005	vM
228	Lal. 23361	8.5	G	12 24.6	− 2 46	0.69	4	G2	G3	+ 7.0	0.158	0.050	+0.095	Y
229	Boss 3274	6.5	K	12 28.0	+10 51	0.063	3	G8	G8	+ 0.3	75.9	0.006	....	....
230	β Can. Ven	4.3	G0	12 29.0	+41 54	0.758	3	G0	G0	+ 4.4	1.74	0.105	+0.096	Y, F
231	Boss 3294	6.0	Ma	12 33.3	+ 2 24	0.090	3	Mb	G9	+ 2.3	12.0	0.018	....	....
232	γ Virginis N	3.7	F0	12 36.6	− 0 54	0.564	3	F0	A8	+ 3.1	5.75	0.076	+0.068	Bel, R, F
233	γ Virginis S	3.7	F0	12 36.6	− 0 54	0.564	3	F0	A8	+ 3.2	5.25	0.079	....	....
234	Boss 3321	6.0	F	12 40.3	+39 49	0.375	3	F6	F7	+ 4.9	1.10	0.060	....	....
235	33 Virginis	5.9	K	12 41.3	+10 6	0.531	3	K2	G9	+ 3.3	4.79	0.030	+0.002	Y, Mil.
236	Lal. 23917	8.3	F8	12 44.6	+ 1 45	0.68	3	G7	G4	+ 6.5	0.251	0.044	+0.029	Y, Sc.
237	δ Virginis	3.7	Ma	12 50.6	+ 3 56	0.479	3	Mb	G7	+ 1.3	30.2	0.033	−0.030	Y
238	Lal. 24168	7.7	G	12 53.9	− 9 18	0.82	3	K1	G9	+ 7.0	0.158	0.072	−0.015	Y
239	ε Virginis	3.0	K0	12 57.2	+11 30	0.273	2	G6	G6	+ 0.4	69.2	0.030	+0.034	F
240	Boss 3398	5.9	Mbp	13 1.5	+23 9	0.066	4	Mc	G9	+ 1.8	19.1	0.015	+0.043	vM
241	Lal. 24414	6.9	G	13 3.8	+ 5 46	0.72	3	G4	G2	+ 3.4	4.37	0.020	+0.008	Y
242	Lal. 24504	8.5	G	13 6.4	+10 9	0.54	3	F8	G2	+ 4.4	1.74	0.015	+0.028	Y
243	β Comae	4.3	G0	13 7.2	+28 23	1.184	3	G1	G0	+ 4.6	1.45	0.115	+0.116	P, F, Y
244	A.G. Ber. 4855	7.8	....	13 7.5	+18 3	0.60	3	F6	F8	+ 5.3	0.759	0.032	....	....
245	Lal. 24652	7.0	....	13 11.9	+17 35	0.70	3	K3	K1	+ 6.7	0.209	0.087	....	....
246	W.B. 13h216	8.8	G5	13 15.7	+ 4 39	0.58	5	K4	K3	+ 6.0	0.398	0.028	−0.021	Y
247	Lal. 24774	8.3	K	13 16.1	+43 38	0.45	3	K0	K0	+ 5.7	0.525	0.030	+0.179	Y
248	70 Virginis	5.2	G5	13 23.5	+14 19	0.634	2	G4	G4	+ 3.1	5.75	0.038	+0.149	Y
249	Lal. 25012	7.5	G	13 26.6	− 1 49	0.91	3	G9	G7	+ 7.5	0.100	0.100	+0.053	Y
250	Boss 3500	6.2	K	13 26.9	+42 37	0.094	3	K0	K0	+ 1.6	22.9	0.012	....	....
251	Boss 3534	5.2	Ma	13 36.4	− 8 12	0.108	3	Ma	G9	+ 1.0	39.8	0.014	....	....
252	A.G. Ber. A. 4999	9.6	....	13 40.2	+18 21	1.92	1	K9	Ma	+10.2	0.008	0.132	+0.094	Sc., R
253	Lal. 25372	8.7	K	13 40.7	+15 26	2.32	3	Ma	Ma	+10.4	0.007	0.219	+0.176	4
254	Boss 3554	6.3	F5	13 42.0	+ 6 51	0.499	4	F9	G0	+ 4.7	1.32	0.048	....	....
255	τ Boötis	4.5	F5	13 42.5	+17 57	0.487	2	F6	F6	+ 3.1	5.75	0.052	+0.040	Y

TABLE I—*Continued*

No.	Name	Harv. Visual Mag.	Harv. Spec.	α 1900	δ 1900	μ	No. Pl.	Spectrum Est.	Spectrum Meas.	Abs. Visual Mag.	Lum.	π	Trig. π	Auth.
256	Boss 3605	6.0	K	13^h53^m8	+15° 8′	0″087	3	K4	K2	+1.1	36.3	0″010	....	....
257	*d* Boötis	4.8	F5	14 5.8	+25 34	0.076	2	F7	F8	+2.6	9.12	0.036	....	....
258	κ Virginis	4.3	K0	14 7.6	−9 48	0.130	2	K2	G9	+1.6	22.9	0.029	....	....
259	Boss 3647	6.3	F5	14 9.1	−5 29	0.317	3	F8	F8	+4.1	2.29	0.036	....	....
260	Boss 3650	5.5	F	14 9.3	+13 26	0.267	3	F7	F7	+4.1	2.29	0.052	+0″097	vM
261	α Boötis	0.2	K0	14 11.1	+19 42	2.282	6	K0	G9	+0.9	43.7	0.138	+0.075	F, Y
262	Lal. 26294	8.3	....	14 17.7	+30 6	0.56	3	K5	K4	+8.7	0.033	0.120	....	....
263	Ber. B. 5072	9.5	....	14 21.1	+24 6	1.38	1	K8	K6	+9.0	0.025	0.079	+0.072	R, L and J
264	θ Boötis	4.1	F8	14 21.8	+52 19	0.471	2	F6	F6	+3.4	4.37	0.072	....	....
265	ρ Boötis	3.8	K0	14 27.5	+30 49	0.149	2	K3	K1	+0.9	43.7	0.026	....	....
266	σ Boötis	4.5	F0	14 30.3	+30 11	0.228	2	F0	F2	+3.5	3.98	0.063	....	....
267	Lal. 26630	6.2	G	14 31.7	−11 53	0.946	3	F5	F5	+4.3	1.91	0.042	+0.049	Y
268	Boss 3736	6.0	K	14 33.6	+18 44	0.096	3	K0	K0	+1.1	36.3	0.011	+0.057	vM
269	μ Virginis	4.0	F5	14 37.8	−5 13	0.339	2	F1	F2	+2.9	6.92	0.060	....	....
270	ε Boötis Br.	2.7	K0p	14 40.6	+27 30	0.049	3	G8	G8	−0.7	191.	0.021	+0.050	F
271	Lal. 27026	7.7	G5	14 46.0	−23 53	1.02	3	K5	K4	+6.6	0.229	0.060	+0.041	F
272	ξ Boötis Br.	4.7	G5	14 46.8	+19 31	0.168	3	G6	G6	+5.5	0.631	0.145}	+0.230	M
273	ξ Boötis Ft.	6.6	....	14 46.8	+19 31	0.168	2	K3	K3	+7.6	0.091	0.158}		
274	Lal. 27137	6.3	....	14 48.8	+19 33	0.53	3	G9	K0	+5.8	0.479	0.079	....	....
275	β Urs. Min.	2.2	K5	14 51.0	+74 34	0.030	2	K4	K1	+0.6	57.5	0.048	+0.014	F
276	Boss 3810	5.6	K	14 51.3	−11 0	0.002	5	K3	K0	+2.2	13.2	0.021	....	....
277	Pi. 14^h212 Br.	5.8	K	14 51.6	−20 58	2.039	3	K5	K6	+6.8	0.191	0.158	+0.174	Sitter, F, M
278	Pi. 14^h212 Ft.	8.7	....	14 51.6	−20 58	2.07	1	Ma	....	+10.1	0.009	0.190	+0.212	M
279	Boss 3816	5.7	G5	14 52.4	+0 14	0.069	3	K1	K1	+1.4	27.5	0.014	+0.044	vM
280	β Boötis	3.6	G5	14 58.2	+40 47	0.063	2	G5	G4	+0.4	69.2	0.023	....	....
281	Lal. 27558	8.7	....	15 3.0	+9 16	0.54	3	F6	F7	+4.7	1.32	0.016	....	....
282	A.Oe. 14318	9.6	K5	15 4.7	−15 59	3.76	1	K0	G8	+6.2	0.331	0.021	+0.035	R, L and J
283	A.Oe. 14320	9.2	G	15 4.7	−15 54	3.75	2	G8	G5	+6.0	0.398	0.023	+0.054	R, L and J
284	Boss 3867	6.0	Mb	15 7.5	+19 21	0.004	3	Mb	G6	+0.4	69.2	0.008	+0.005	vM
285	Lal. 27742	6.8}	G	{15 8.2	+19 39	0.68	3	G6	G3	+3.9	2.75	0.026	+0.018	R, Y
286	Lal. 27743	7.6}		{15 8.2	+19 40	0.62	4	G9	G5	+4.9	1.10	0.029	−0.071	R
287	3 Serpentis	5.2	K0	15 10.2	+5 19	0.023	2	G9	G6	+0.2	83.2	0.009	....	....
288	δ Boötis	3.5	K0	15 11.4	+33 41	0.155	2	G5	G4	+0.2	83.2	0.022	....	....
289	5 Serpentis	5.2	G	15 14.2	+2 9	0.644	2	F7	F7	+4.2	2.09	0.063	+0.094	Y
290	Lal. 27958	8.0	G	15 14.8	+26 4	0.51	3	G8	G6	+4.3	1.91	0.018	+0.031	Y
291	Boss 3900	6.2	G	15 15.2	−17 48	0.069	4	G9	G6	+0.6	57.5	0.008	....	....
292	6 Serpentis	5.5	K	15 15.9	+1 5	0.125	3	K5	K2	+2.5	10.0	0.025	+0.133	F
293	W.B. 15^h268	8.7	K5	15 17.7	+1 47	0.52	3	K4	K4	+6.3	0.302	0.033	+0.118	Y
294	η Coronae	5.6	G	15 19.1	+30 39	0.237	3	G0	G0	+4.8	1.20	0.069	+0.078	S
295	μ^1 Boötis	4.5	F0	15 20.7	+37 44	0.169	3	F0	....	+3.1	5.75	0.052	+0.039	Mil.

296	μ² Boötis	6.7	K	15 20.7	+37 44	0.169	3	Go	Go	+ 5.3	0.759	0.052	+0.055	F, Mil.
297	τ¹ Serpentis	5.5	Ma	15 21.2	+15 47	0.033	2	K6	K1	+ 1.1	36.3	0.013	....	....
298	β Cor. Bor	3.7	Fp	15 23.7	+29 27	0.190	3	F2p	F2	+ 1.2	33.1	0.032	....	....
299	Lal. 28358	6.9	F8	15 26.6	+57 47	0.29	3	F5	F5	+ 4.2	2.09	0.029	+0.029	F
300	Boss 3952	4.8	K	15 28.7	− 9 43	0.389	3	K2	G9	+ 1.5	25.1	0.022	....	....
301	γ Librae	4.0	Ko	15 29.9	−14 27	0.065	2	G9	G8	+ 0.4	69.2	0.019	....	....
302	Boss 3963	6.1	K	15 31.0	+17 59	0.081	5	G7	G6	+ 0.8	47.9	0.009	....	....
303	α Serpentis	2.8	Ko	15 39.3	+ 6 44	0.130	3	K1	K1	+ 0.2	83.2	0.030	+0.151	F
304	κ Serpentis	4.3	K5	15 44.2	+18 27	0.110	2	K7	Ko	+ 0.9	43.7	0.021	....	....
305	39 Serpentis	6.2	G	15 48.5	+13 31	0.586	4	G1	G1	+ 5.5	0.631	0.072	+0.040	Y
306	Boss 4048	5.8	K5	15 50.2	+20 36	0.083	3	K4	G8	+ 0.9	43.7	0.011	+0.040	vM
307	γ Serpentis	3.9	F8	15 51.8	+15 59	0.133	2	F4	F5	+ 3.9	2.75	0.100	+0.066	4
308	W.B. 15^h1323	8.0	....	15 54.5	+28 1	0.85	3	G8	G9	+ 6.4	0.275	0.048	....	....
309	Lal. 29085	5.5	F	15 54.7	−16 14	0.75	6	F5	F5	+ 4.2	2.09	0.055	....	....
310	ρ Cor. Bor	5.4	F	15 57.2	+33 36	0.81	3	F8	F9	+ 3.9	2.75	0.050	+0.031	Y
311	Lal. 29307	7.5	....	15 59.9	+25 31	0.87	3	Ko	G8	+ 5.4	0.692	0.038	+0.058	S
312	θ Draconis	4.1	F8	16 0.0	+58 50	0.459	2	F7	F8	+ 3.6	3.63	0.079	+0.066	Kostinsky
313	Lal. 29330	8.5	....	16 1.2	+10 57	0.50	7	Ko	G9	+ 7.4	0.110	0.060	....	....
314	Lal. 29381	6.8	G5	16 1.5	+39 26	0.55	3	G8	G6	+ 6.7	0.209	0.096	+0.069	Y
315	Boss 4096	5.6	Ma	16 2.0	−26 4	0.122	3	Ma	G8	+ 2.0	15.8	0.019	....	....
316	Lal. 29439	9.2	G5	16 2.9	+38 55	0.60	3	K4	K2	+ 7.1	0.145	0.038	+0.014	Y, K
317	κ Herculis	5.3	G5	16 3.6	+17 19	0.046	2	G6	G4	+ 0.1	91.2	0.009	−0.004	L and J
318	τ Cor. Bor	4.9	K	16 5.3	+36 45	0.325	4	Ko	Ko	+ 2.0	15.8	0.026	+0.102	F
319	Boss 4130	5.6	G5	16 8.3	+ 5 17	0.046	3	K4	K2	+ 1.1	36.3	0.012	+0.008	vM
320	δ Ophiuchi	3.0	Ma	16 9.1	− 3 26	0.161	3	Ma	G8	+ 2.2	13.2	0.069	....	....
321	Lal. 29617	5.6	F	16 10.2	− 8 6	0.563	5	F9	G1	+ 4.4	1.74	0.058	+0.039	Y
322	σ Coronae Ft	6.8	....	16 10.9	+34 7	0.302	4	F9	F9	+ 5.1	0.912	0.046	+0.031	F
323	σ Coronae Br	5.8	Go	16 10.9	+34 7		4	F8p	G1	+ 4.4	1.74	0.052		
324	Lal. 29917	8.6	K2	16 16.5	+67 29	0.50	3	K7	K5	+ 8.0	0.063	0.076	+0.151	Y
325	ν¹ Cor. Bor	5.4	Ma	16 18.6	+34 2	0.049	2	Ma	G9	+ 0.9	43.7	0.013	....	....
326	ν² Cor. Bor	5.3	K5	16 18.7	+33 56	0.055	2	K6	K2	+ 1.6	22.9	0.018	....	....
327	η Draconis	2.9	G5	16 22.6	+61 44	0.062	3	G6	G5	+ 0.9	43.7	0.040	+0.019	F, M
328	α Scorpii	1.2	Map	16 23.3	−26 13	0.034	2	Ma	G2	− 3.0	1584.	0.014	+0.030	Finlay
329	Lal. 30024	7.0	G5	16 24.5	+18 37	0.53	3	K2	K2	+ 7.2	0.132	0.110	+0.088	Y
330	Lal. 30044	7.3	G	16 25.6	+ 4 26	1.46	3	F6	F6	+ 5.5	0.631	0.044	+0.011	F, Y
331	β Herculis	2.8	Ko	16 25.9	+21 42	0.107	2	G6	G7	− 0.1	110.	0.026	+0.020	F
332	Boss 4222	5.9	F	16 31.1	− 2 7	0.546	3	G9	G9	+ 5.4	0.692	0.079	....	....
333	Lal. 30271	7.2	G	16 32.6	+31 9	0.49	3	F6	F6	+ 5.2	0.832	0.040	+0.012	Y
334	Gro. 19 Area VII 308	8.6	....	16 34.1	+51 45	0.115	3	G2	G2	+ 4.5	1.58	0.015	+0.017	K
335	ζ Herculis	3.0	Go	16 37.5	+31 47	0.608	3	G1	G1	+ 2.1	14.5	0.066	+0.118	4
336	Boss 4262	5.8	Ma	16 40.8	+15 56	0.054	3	Mb	G9	+ 1.8	19.1	0.016	+0.022	vM
337	W.B. 16^h906	8.8	K	10 50.1	− 8 9	1.27	4	Md	....	+10.0	0.010	0.174	+0.150	Y, L and J
338	Boss 4303	6.5	G	16 50.2	−16 39	0.089	3	Ko	Ko	+ 3.0	6.31	0.020	....	....
339	Boss 4307	5.5	F	16 50.6	+21 7	0.059	3	G7	G6	+ 0.9	43.7	0.012	+0.001	vM
340	Boss 4326	6.4	K	16 56.0	−18 44	0.052	3	G9	G8	+ 0.9	43.7	0.008	....	....
341	Boss 4371	5.2	K	17 9.2	−26 27	1.224	3	K2	K1	+ 6.3	0.302	0.166	+0.152	F
342	α Herculis	3.1–3.9	Mb	17 10.1	+14 30	0.030	2	Mc	G5	− 0.7	191.	0.012–0.017	....	....

TABLE I—*Continued*

No.	Name	Harv. Visual Mag.	Harv. Spec.	α 1900	δ 1900	μ	No. Pl.	Spectrum Est.	Spectrum Meas.	Abs. Visual Mag.	Lum.	π	Trig. π	Auth.
343	Boss 4393	5.8	K	$17^h14^m.9$	+28° 56′	0″.045	4	G8	G8	+ 0.6	57.5	0″.009	+0″.015	vM
344	72 Herculis	5.4	G	17 16.9	+32 36	1.06	4	F8	G1	+ 5.8	0.479	0.120	+0.123	F, Y
345	Lal. 32047	6.3	K	17 25.3	+67 23	0.52	3	G9	G8	+ 5.9	0.437	0.083	+0.062	Y, Gr
346	B.D. +1°3450	7.2	K2	17 26.5	+ 1 45	....	3	K3	K4	+ 1.8	19.1	0.008	+0.039	Y
347	λ Herculis	4.5	K0	17 26.7	+26 11	0.021	3	K2	K1	+ 0.5	63.1	0.016	....	....
348	W.B. 17^h514	8.6	G	17 29.9	+ 6 4	0.58	4	F5	F6	+ 4.4	1.74	0.014	−0.004	Y
349	Anon	9.1	....	17 33.5	+18 37	1.29	1	K8	K6	+10.0	0.010	0.151	+0.128	S and M, L and J
350	26 Draconis	5.3	F	17 34.0	+61 57	0.563	2	G0	G0	+ 4.7	1.32	0.076	+0.087	Y, Mil.
351	B.D. +18°3424	9.2	....	17 34.3	+18 37	0.09	1	K1	K0	+ 6.5	0.251	0.029	+0.008	S and M
352	Lal. 32322	8.4	....	17 36.3	+37 16	0.88	3	F7	F9	+ 5.0	1.00	0.021	....	....
353	A.Oe. 17415	9.1	K	17 37.0	+68 26	1.30	5	Mb	Mb	+10.6	0.006	0.200	+0.254	4
354	Boss 4480	6.5	F8	17 37.0	+24 34	0.052	3	K1	K1	+ 0.6	57.5	0.007	+0.020	vM
355	Lal. 32390	7.5	....	17 39.0	+21 40	0.61	3	G8	G6	+ 5.9	0.437	0.048	....	....
356	μ Herculis	3.5	G5	17 42.5	+27 47	0.817	3	G5	G4	+ 3.2	5.25	0.087	+0.095	4
357	Comp. μ Herculis	9.7	....	17 42.5	+27 47	0.817	1	Mb	....	+ 9.6	0.014	0.096	+0.056	R
358	Barnard's P.M. Star	9.7	....	17 52.9	+ 4 25	10.3	3	Mb	....	+13.3	0.0005	0.50	+0.50	Sc. (Allegheny)
359	γ Draconis	2.4	K5	17 54.3	+51 30	0.027	3	K5	K1	+ 1.4	27.5	0.063	+0.015	4
360	Boss 4555	5.9	K	17 57.1	+45 30	0.044	3	K6	K3	+ 1.5	25.1	0.013	+0.026	vM
361	B.D. +26°3151	7.3	....	17 58.4	+26 20	0.66	3	K0	K0	+ 6.1	0.363	0.058	....	....
362	70 Ophiuchi Br	4.1	K0	18 0.4	+ 2 31	1.131	3	K0	G9	+ 5.6	0.575	0.200	+0.187	6
363	70 Ophiuchi Ft	6.0	....	18 0.4	+ 2 31	1.131	3	K5	K7	+ 7.6	0.091	0.209	+0.170	M
364	99 Herculis Br	5.2	F8	18 3.2	+30 33	0.113	3	F4	F6	+ 5.3	0.759	0.105	+0.074	F
365	Lal. 33439	6.7	G5	18 6.3	+38 27	0.62	3	K2	K2	+ 6.4	0.275	0.087	+0.045	Y
366	Boss 4629	5.5	K	18 15.1	+24 24	0.016	3	K2	K0	+ 0.4	69.2	0.010	+0.002	vM
367	η Serpentis	3.4	K0	18 16.1	− 2 55	0.898	3	G8	G7	+ 1.8	19.1	0.048	+0.057	Y, Jw.
368	Boss 4647	6.2	K	18 17.6	+51 18	0.062	3	K1	K0	+ 0.5	63.1	0.008	+0.036	vM
369	109 Herculis	3.9	K0	18 19.4	+21 43	0.324	2	K2	K1	+ 1.0	39.8	0.026	+0.029	Jo.
370	Gro. 19, Area II 66	7.7	G5	18 21.4	+ 8 44	0.498	3	G5	G4	+ 6.3	0.302	0.052	+0.037	K
371	Gro. 19, Area II 75	8.1	G5	18 21.6	+ 8 34	0.498	3	G8	G8	+ 4.3	1.91	0.018	....	....
372	λ Sagittarii	2.9	K0	18 21.8	−25 29	0.197	2	K0	G9	+ 2.3	12.0	0.076	+0.069	F
373	Gro. 19, Area II 90	8.6	G5	18 22.0	+ 8 3	0.157	3	G1	G0	+ 5.3	0.759	0.022	+0.015	K
374	χ Draconis	3.7	F8	18 22.9	+72 41	0.638	4	F5	F6	+ 5.0	1.00	0.182	+0.105	Y, Gr., M
375	1 Aquilae	4.1	K0	18 29.8	− 8 19	0.318	2	K4	K2	+ 1.1	36.3	0.025	....	....
376	A.G. Leid. 6797	8.7	....	18 37.1	+31 28	0.82	3	K3	K2	+ 7.3	0.120	0.052	....	....
377	110 Herculis	4.3	F5	18 41.4	+20 27	0.345	3	F4	F4	+ 3.5	3.98	0.069	+0.080	M, Jo.
378	Pos. Med. 2164[1]	8.9	K	18 41.7	+59 29	2.28	2	Mb	Mb	+10.7	0.005	0.229	+0.290	R, Sc.
379	o Draconis	4.8	K0	18 49.7	+59 16	0.086	3	G8	G4	− 0.2	120.	0.010	....	....
380	R Lyrae	{4.0– 4.7}	Mb	18 52.3	+43 49	0.077	3	Mc	G8	+ 0.8	47.9	{0.016– 0.023}	+0.028	Ab.
381	Munich 18180	9.4	Ma	18 53.1	+ 5 48	1.24	3	K7	K6	+ 9.2	0.021	0.091	+0.069	R, Sc.

382	Brad. 2388	5.2	G	18 53.3	+32 46	0.23	3	F7	F9	+ 4.7	1.32	0.079	+0.116	F, Jw., Mil.
383	Boss 4860	5.8	K	19 1.2	+31 36	0.085	3	K5	K1	+ 1.4	27.5	0.013	+0.026	vM
384	Munich 18816	9.3	K	19 2.2	+ 7 29	0.80	3	K5	K3	+ 8.0	0.063	0.055	+0.040	Sc.
385	Boss 4892	6.8	K	19 9.5	+49 40	0.63	4	G4	G3	+ 5.5	0.631	0.055	+0.038	R, M, vM
386	Boss 4893	6.6	K	19 9.5	+49 40	0.654	4	G6	G2	+ 5.5	0.631	0.060	+0.052	R, M, vM
387	δ Draconis	3.2	Ko	19 12.5	+67 29	0.133	2	G9	G7	+ 0.5	63.1	0.029	....	....
388	θ Lyrae	4.5	K	19 12.9	+37 57	0.012	5	G9	G7	− 0.8	209.	0.009	....	....
389	Boss 4915	6.3	A	19 13.3	−15 43	0.285	4	K2	G9	+ 1.7	20.9	0.011	....	....
390	Boss 4920	6.0	F	19 14.0	+46 49	0.285	3	F4	F5	+ 3.2	5.25	0.027	....	....
391	κ Cygni	4.0	Ko	19 14.8	+53 11	0.133	3	G7	G7	+ 0.9	43.7	0.024	+0.062	Ab.
392	3 Cygni	6.2	K	19 21.3	+24 44	0.658	2	F6	F4	+ 4.1	2.29	0.038	+0.060	Y, Jo., F
393	Boss 4976	4.6	Ma	19 24.5	+24 28	0.170	4	Ma	K1	+ 1.6	22.9	0.025	....	....
394	Groom. 2875	6.7	G5	19 29.5	+58 23	0.66	3	K3	K2	+ 6.1	0.363	0.076	−0.055	Y
395	Lal. 37120	6.6	G	19 29.7	+32 59	0.52	4	F9	F9	+ 4.6	1.45	0.040	+0.058	Y
396	σ Draconis	4.8	K	19 32.6	+69 29	1.840	3	G8	G7	+ 5.4	0.692	0.132	+0.198	4
397	θ Cygni	4.6	F5	19 33.8	+49 59	0.249	3	F3	F4	+ 3.7	3.31	0.066	+0.073	Y, F, M, Ab.
398	54 Sagittarii	5.4	Ko	19 35.0	−16 31	0.085	2	K1	Ko	+ 0.8	47.9	0.012	....	....
399	Boss 5037	6.3	F	19 39.2	+50 18	0.217	3	G1	G1	+ 5.3	0.759	0.063	+0.048	S and M
400	Boss 5038	6.4	F5	19 39.2	+50 17	0.220	4	G4	G3	+ 4.4	1.74	0.040	+0.033	S and M
401	Boss 5043	6.0	K	19 40.4	+41 32	0.017	3	K6	K1	+ 0.9	43.7	0.009	+0.006	vM
402	Boss 5044	5.1	K	19 40.5	−20 0	0.165	3	Ko	G9	+ 0.1	91.2	0.010	....	....
403	γ Aquilae	2.8	K2	19 41.5	+10 22	0.014	2	K3	G9	+ 0.3	75.9	0.032	−0.009	F
404	δ Sagittae	3.8	Map	19 42.9	+18 17	0.009	3	Ma	G1	+ 1.8	19.1	0.040	....	....
405	η Aquilae	{3.7–4.4}	Go	19 47.4	+ 0 45	0.012	3	(F9)	(Go)	+ 0.5	63.1	{0.016–0.023}	+0.006	M
406	β Aquilae	3.9	Ko	19 50.4	+ 6 9	0.484	4	G8	G7	+ 3.2	5.25	0.072	+0.071	M
407	Lal. 38100	6.3	F8	19 54.4	−10 13	0.488	3	F9	F8	+ 4.6	1.45	0.046	−0.004	Y
408	Lal. 38139	7.3	....	19 55.5	−12 31	0.50	3	F4	F5	+ 4.9	1.10	0.033	....	....
409	Lal. 38287	7.2	G	19 58.0	+15 20	0.60	3	G8	G5	+ 6.6	0.229	0.076	+0.088	Y
410	Lal. 38380	5.7	G5	19 59.5	+29 38	0.86	3	G9	G7	+ 4.0	2.51	0.046	+0.050	Y, F
411	Boss 5146	5.9	G	19 59.6	+16 48	0.557	3	F9	Go	+ 5.2	0.832	0.072	+0.104	Y, Jo.
412	Lal. 38383	7.2	G	19 59.7	+23 5	1.39	3	K2	Ko	+ 7.6	0.091	0.120	+0.099	Jw., Y, F
413	Boss 5157	5.5	K	20 2.6	+35 42	0.496	3	G9	G6	+ 3.0	6.31	0.032	....	....
414	Groom. 3042	5.7	A	20 3.6	+52 52	0.334	4	F4	F4	+ 4.5	1.58	0.057	+0.066	Y, Ab.
415	Lal. 38683	7.3	G5	20 6.6	+15 53	0.55	3	K1	K1	+ 6.7	0.209	0.076	+0.077	Y
416	Lal. 38711	5.7	G2	20 9.0	−27 20	1.256	3	K3	K2	+ 4.9	1.10	0.069	....	....
417	Boss 5184	5.7	F	20 9.9	+61 47	0.155	3	F6	F4	+ 2.5	10.0	0.023	+0.037	vM
418	o² Cygni	4.0	Kop	20 10.5	+46 26	0.002	3	G9p	G1	+ 1.2	33.1	0.028	+0.003	M
419	24 Vulpeculae	5.4	Ko	20 12.5	+24 22	0.027	3	G7	G5	+ 0.7	52.5	0.012	....	....
420	A.G. Cam. 6486	7.4	....	20 15.9	+55 5	0.81	4	F3	F4	+ 3.7	3.31	0.018	....	....
421	Groom. 3150	6.1	G	20 16.5	+66 32	0.557	3	F7	Go	+ 6.1	0.363	0.100	+0.120	Y, Jw.
422	A.Oe. 20452	8.1	F8	20 17.7	−21 40	1.22	4	F6	F7	+ 4.8	1.20	0.022	....	....
423	γ Cygni	2.3	F8p	20 18.6	+39 56	0.003	3	F9p	Go	+ 1.3	30.2	0.063	+0.072	F, Y
424	Boss 5263	5.8	G	20 26.9	−10 12	0.317	6	G4	G2	+ 4.3	1.91	0.050	+0.035	F
425	Lal. 39704	7.0	G5	20 29.3	+41 33	0.50	3	Ko	G7	+ 6.4	0.275	0.076	+0.007	Y, Jo.
426	β Delphini	3.7	F5	20 32.9	+14 15	0.113	3	F3	F3	+ 1.6	22.9	0.038	+0.017	F, M, Mil.
427	Lal. 39866	8.4	K	20 34.6	+ 4 37	0.85	6	K5	K3	+ 8.0	0.063	0.083	+0.068	Y, Sc.

TABLE I—*Continued*

No.	Name	Harv. Visual Mag.	Harv. Spec.	α 1900	δ 1900	μ	No. Pl.	Spectrum Est.	Spectrum Meas.	Abs. Visual Mag.	Lum.	π	Trig. π	Auth.
428	Groom. 3263	6.0	F	20h38m2	+60° 9′	0″186	3	F5	F6	+ 4.4	1.74	0″048	+0″049	Y, Ab.
429	γ Delphini Br.	4.5	G5	20 42.0	+15 46	0.207	3	K1	K1	+ 1.2	33.1	0.022	+0.076	M
430	ε Cygni	2.6	K0	20 42.2	+33 36	0.483	2	G8	G7	+ 0.8	47.9	0.044	+0.016	4
431	η Cephei	3.6	K0	20 43.3	+61 27	0.826	3	G9	G8	+ 2.4	11.0	0.058	+0.116	Y, Ab., S and M
432	Fed. 3638	7.8	G5	20 52.4	+74 23	0.70	3	G6	G4	+ 5.2	0.832	0.030	−0.020	Y, F
433	ε Equulei	5.3	F5	20 54.1	+ 3 55	0.191	4	F2	F3	+ 3.2	5.25	0.038	+0.048	M
434	Groom. 3357	6.6	G	20 56.1	+39 51	0.33	3	F7	F8	+ 4.6	1.45	0.040	+0.077	Jo.
435	W.B. 20h1454	8.0	F8	20 59.1	+ 2 36	0.55	3	F6	F6	+ 5.0	1.00	0.025	−0.066	Y
436	Lal. 40844	8.8	K	21 0.4	+ 6 41	0.57	4	K6	K4	+ 8.7	0.033	0.096	+0.167	Y
437	61¹ Cygni	5.6	K5	21 2.4	+38 15	5.271	6	K7	K7	+ 7.9	0.069	0.288	+0.313	16
438	61² Cygni	6.3	K5	21 2.4	+38 15	5.157	6	K8	K7	+ 8.7	0.033	0.302	+0.309	16
439	B.D. +38°4362	7.9	K2	21 5.2	+38 19	......	3	K2	G9	+ 1.2	33.1	0.005	−0.031	R
440	W.B. 21h97	7.3	F8	21 7.4	+17 21	0.91	3	F3	F2	+ 5.8	0.479	0.050	+0.018	Y, F, Jw.
441	ζ Cygni	3.4	K0	21 8.7	+29 49	0.059	3	G6	G7	− 0.4	145.	0.017	+0.048	M
442	δ Equulei	5.0	F5	21 9.6	+ 9 36	0.306	4	F4	F5	+ 4.0	2.51	0.063	+0.067	F, Hus.
443	τ Cygni	3.8	F0	21 10.8	+37 37	0.455	3	F1	F1	+ 1.9	17.4	0.042	+0.031	4
444	Lal. 41363	6.5	G	21 14.0	−26 46	0.67	2	G9	G5	+ 5.1	0.912	0.052	......	......
445	Boss 5519	5.7	F	21 23.9	+31 47	0.134	3	F0	F1	+ 3.7	3.31	0.040	+0.032	vM
446	W.B. 21h502	9.1	......	21 24.5	−12 56	1.06	2	K5	K6	+ 8.6	0.036	0.079	......	......
447	g Cygni	5.3	K0	21 25.8	+46 6	0.114	3	G9	G8	+ 1.0	39.8	0.014	+0.042	Ab., Mil.
448	ρ Cygni	4.2	K	21 30.2	+45 9	0.095	2	G6	G4	+ 2.1	14.5	0.038	+0.042	Y, Ab.
449	Boss 5559	6.8	F5	21 34.4	− 0 30	0.236	4	F6	F6	+ 5.2	0.832	0.048	+0.017	F, Jw.
450	ε Pegasi	2.5	K0	21 39.3	+ 9 25	0.025	3	K0	G4	− 0.3	132.	0.028	+0.041	F
451	A.G. Ber. 8366	8.8	......	21 39.7	+24 53	0.68	3	K1	G7	+ 6.3	0.302	0.032	......	......
452	κ Pegasi	4.3	F5	21 40.1	+25 11	0.033	3	F2	F3	+ 3.4	4.37	0.066	+0.040	5
453	Boss 5602	6.5	K	21 41.8	+25 6	0.148	4	K3	K2	+ 1.5	25.1	0.010	......	......
454	Lal. 42883	6.8	F5	21 54.2	+29 21	0.54	4	F6	F4	+ 5.9	0.437	0.066	+0.041	Y, F, Jw.
455	α Aquarii	3.2	G0	22 0.6	− 0 48	0.015	2	G0p	F8	+ 0.2	83.2	0.025	+0.010	M
456	Boss 5682	(7.1)	F8	22 1.8	+82 23	0.142	3	F6	F7	+ 3.8	3.02	0.022	+0.007	vM
457	ι Pegasi	4.0	F5	22 2.4	+24 51	0.299	3	F3	F4	+ 4.0	2.51	0.100	+0.097	M, Mil.
458	Boss 5691	5.8	F	22 2.7	+18 59	0.126	3	F1	F3	+ 3.3	4.79	0.032	+0.013	vM
459	Lal. 43205	8.0	G5	22 3.1	+52 39	0.61	3	K0	G7	+ 3.6	3.63	0.013	+0.051	4
460	Lal. 43492	6.9	G	22 12.2	+12 24	0.84	3	G1	G0	+ 5.8	0.479	0.060	+0.015	4
461	Boss 5772	6.1	G	22 18.8	+20 21	0.338	6	F5	F5	+ 4.5	1.58	0.048	+0.060	vM
462	Boss 5786	5.8	G	22 21.5	+ 3 53	0.295	4	F5	F6	+ 4.1	2.29	0.046	+0.067	F, Jw.
463	Boss 5790	4.9	K	22 22.8	+ 4 12	0.325	4	G0	G0	+ 1.3	30.2	0.019	......	......
464	Krüger 60	9.2	K5	22 24.5	+57 12	0.94	4	Mb	Mb	+11.2	0.003	0.251	+0.256	Sc., R, Bar.
465	η Pegasi	3.1	G0	22 38.3	+29 42	0.036	2	G2	G3	+ 1.2	33.1	0.042	−0.028	F
466	Boss 5868	6.1	K	22 39.6	+38 56	0.016	3	K4	K3	+ 0.9	43.7	0.009	+0.011	vM
467	Pi. 22h214	6.5	G5	22 40.9	+29 55	0.47	4	K0	G8	+ 4.4	1.74	0.038	+0.015	Y, L and J

468	λ Pegasi	4.1	K0	22 41.7	+23 2	0.060	2	G7	G6	− 0.5	158.	0.012	....	....
469	ι Cephei	3.7	K0	22 46.1	+65 40	0.139	2	K0	G9	+ 1.1	36.3	0.030	+0.036	M
470	σ Pegasi	5.3	F	22 47.3	+ 9 18	0.516	3	F4	F5	+ 3.9	2.75	0.052	+0.033	Y, F
471	Boss 5920	6.5	F5	22 53.5	+ 8 50	0.420	3	G0	F9	+ 4.4	1.74	0.038	....	....
472	Lal. 45028	7.8	K	22 56.6	− 4 23	0.54	4	K2	K3	+ 5.8	0.479	0.040	+0.053	Y, M
473	β Pegasi	2.6	Ma	22 58.9	+27 32	0.234	3	Mb	G7	+ 1.3	30.2	0.055	....	....
474	Fed. 4371	7.5	G	23 1.2	+67 52	0.60	3	G5	G1	+ 7.0	0.158	0.079	+0.056	Y
475	Lal. 45292	8.2	K	23 4.0	− 2 48	0.59	3	K5	K3	+ 6.6	0.229	0.048	+0.035	Y
476	Boss 5972	5.8	A	23 5.8	+43 0	0.275	3	F5	F4	+ 4.1	2.29	0.046	....	....
477	Boss 5976	5.6	K	23 8.5	+56 37	2.105	3	K5	K6	+ 6.6	0.229	0.158	+0.172	4
478	Lal. 45455	8.6	....	23 8.9	− 9 28	0.56	4	F4	F6	+ 5.1	0.912	0.020	....	....
479	Lal. 45456	9.0	F5	23 8.9	− 9 29	0.55	4	G0	G2	+ 5.8	0.479	0.023	+0.019	Y
480	ψ¹ Aquarii	4.5	K0	23 10.6	− 9 38	0.367	4	K0	G9	+ 1.1	36.3	0.021	....	....
481	γ Piscium	3.8	K0	23 12.0	+ 2 44	0.753	3	G5	G4	+ 1.2	33.1	0.030	−0.041	Y
482	Boss 5989	5.6	F	23 12.1	+52 40	0.270	3	F9	F8	+ 4.1	2.29	0.050	+0.049	vM
483	Lal. 45638	8.2	G5	23 13.8	+ 4 52	0.52	3	K2	G9	+ 6.6	0.229	0.048	+0.016	Y, Jw., M
484	W.B. 23^h257	8.5	....	23 15.0	+28 19	0.57	3	K1	K1	+ 6.8	0.191	0.046	+0.060	S
485	Lal. 45755	7.6	F8	23 16.8	+43 33	0.67	3	K0	G7	+ 6.3	0.302	0.055	+0.039	Y, R
486	υ Pegasi	4.6	G0	23 20.4	+22 51	0.191	3	F6	F6	+ 2.5	10.0	0.038	....	....
487	A. Oe. 25685	7.5	....	23 26.5	+58 37	1.08	3	K0	K0	+ 5.8	0.479	0.046	+0.075	Y
488	B.D. $+62°2244$	7.3	G5	23 28.2	+62 36	0.44	3	G5	G3	+ 4.3	1.91	0.025	−0.012	Y
489	ι Piscium	4.3	G0	23 34.8	+ 5 5	0.574	3	F5	F7	+ 4.3	1.91	0.100	+0.142	Y, Jw.
490	γ Cephei	3.4	K0	23 35.2	+77 4	0.169	2	K1	K1	+ 2.4	11.0	0.063	+0.071	S and M
491	Lal. 46495	7.0	G	23 38.5	+57 31	0.62	3	G0	F9	+ 4.9	1.10	0.038	−0.062	Y,F
492	Boss 6097	6.6	G	23 39.9	+55 15	0.029	3	G6	G6	+ 0.7	52.5	0.007	+0.008	vM
493	W.B. 23^h819	8.6	....	23 40.0	+29 0	0.85	2	K1	K1	+ 7.4	0.110	0.058	....	....
494	τ Cassiop.	5.1	K	23 42.2	+58 6	0.087	4	K0	G9	+ 0.6	57.5	0.013	....	....
495	Lal. 46650	8.9	Ma	23 44.0	+ 1 52	1.39	4	Ma	Ma	+10.3	0.008	0.190	+0.182	5
496	Boss 6129	6.6	K	23 47.5	+74 59	0.332	7	K3p	K3	+ 7.2	0.132	0.132	....	....
497	ρ Cassiop.	5.0	F8p	23 49.4	+56 57	0.007	5	G4p	G3	− 0.4	145.	0.008	....	....
498	B.D. $+26°4721$	7.8	....	23 54.2	+26 43	....	3	K2	G6	+ 0.1	91.2	0.003	....	....
499	85 Pegasi	5.9	G	23 56.9	+26 33	1.291	5	G1	G1	+ 5.8	0.479	0.096	+0.099	5
500	Lal. 47207	6.2	G	23 59.6	+34 6	0.78	3	G0	G0	+ 4.4	1.74	0.044	+0.008	Y

the results obtained by three observers, Adams, Joy, and Miss Burwell. The successive columns of the table contain the following data: (1) number of the star; (2) name of star; (3) visual magnitude as given by the Harvard observers wherever possible; (4) spectral type from Harvard determinations; for the fainter stars many of the values are taken from the recent list of measured parallaxes compiled by Walkey;[1] (5) right ascension; (6) declination; (7) total proper motion; (8) number of photographs of spectrum; (9) spectrum as determined from estimates of the general characteristics of the lines; (10) spectrum as determined from the intensities of the hydrogen lines; (11) absolute visual magnitude; (12) luminosity in terms of the sun as unity, the value 5.0 being taken as the sun's absolute magnitude; (13) parallax as computed from the absolute magnitude by the formula $5 \log \pi = M - m - 5$; (14) measured or trigonometric parallax; (15) authorities for the measured parallax; when these exceed three a figure is given in this column to indicate the number of determinations. The following abbreviations are used:

Ab.	Abetti	M	Mitchell (McCormick)
Bar.	Barnard	Mil.	Miller
Bel.	Belopolsky	Ram.	Rambaut
Bg.	Bergstrand	R	Russell
F	Flint	S	Slocum (Yerkes)
Gr.	Greenwich	Sc.	Schlesinger (Yerkes)
Hus.	Hussey	S. and M.	Slocum and Mitchell (Yerkes)
Jw.	Jewdokimow		
Jo.	Jost	vM	van Maanen
K	Kapteyn	Y	Yale
L and J	Lee and Joy (Yerkes)		

It is with considerable hesitation that we have decided to give values of the parallax resulting from the absolute magnitudes to three decimal places. From the relation connecting parallax and magnitude it follows that

$$\frac{d\pi}{\pi} = \frac{dM - dm}{2.2}$$

The percentage uncertainty in a calculated parallax is therefore proportional to the uncertainty in the magnitudes; but the abso-

[1] *Journal of British Astronomical Association*, 27, Appendix, 1917.

lute error depends upon the parallax itself. For many stars, particularly those of large parallax upon which even moderate errors in the magnitudes have a marked influence, the third decimal is probably undesirable. On the other hand, because of uniformity and the universal practice in the case of measured parallaxes, it has seemed preferable to retain it. An additional reason is the great number of stars of very small parallax. Attention should be called to the influence of uncertainties in the apparent magnitudes upon the parallaxes. In the case of some of the fainter stars and the components of close pairs this may be very appreciable.

NOTES ON INDIVIDUAL STARS

No. 45. This star is Boss 637. The mean spectral type is given and the mean magnitude is used for the computation of the parallax.

Nos. 69, 71, 72, 73. These are the brightest stars of the Hyades and form part of the moving cluster in Taurus. The parallax of this cluster as computed by Kapteyn is $+0\overset{''}{.}023$.

No. 125. The spectrum contains bright hydrogen lines, but the bands are not sufficiently strong for classification as Md.

No. 248. An unpublished parallax kindly communicated by Professor Mitchell is $+0\overset{''}{.}050$.

No. 303. An unpublished parallax by Mitchell is $+0\overset{''}{.}043$.

No. 357. The apparent magnitude is uncertain.

No. 358. This star is used as a standard for reduction of absolute magnitudes. Hence the parallax agreement is necessary.

No. 405. The mean spectral type is given.

No. 456. The apparent magnitude is uncertain.

No. 496. This star has a composite spectrum and is a spectroscopic binary. The absolute magnitudes show a considerable range on different photographs.

COMPARISON WITH THE MEASURED PARALLAXES

There are in the list 360 stars with measured parallaxes. If we divide these stars according to spectral type and absolute magnitude we obtain the comparison given in Table II. The differences Δ are spectroscopic *minus* measured values. The mean difference,

accordingly, for the 360 stars is $+0\rlap{.}''0037$, the spectroscopic values being the larger. The very large discordance in the case of the K3–K9 stars under M = +2.0 to 4.9 is due to No. 292 of the list with but a single measured parallax. The average difference taken

TABLE II

Type	M = −3.0 to +1.9		+2.0 to +4.9		+5.0 to +7.9		+8.0 to +13.3		Total	
	No.	Δ	No.	Δ	No.	Δ	No.	Δ	No.	Δ
F0–F8...	12	+0″003	62	+0″004	14	+0″018	.....	....	88	+0″006
F9–G7...	22	+0.005	35	+0.007	34	+0.007	.....	....	91	+0.007
G8–K2...	38	−0.004	21	−0.011	35	+0.002	2	−0.021	96	−0.004
K3–K9...	16	+0.011	1	−0.108	23	+0.014	17	+0.005	57	+0.008
Ma–Md..	14	+0.004	1	−0.049	.....	....	13	+0.008	28	+0.004
All....	102	+0.002	120	+0.001	106	+0.008	32	+0.004	360	+0.0037

regardless of sign between the spectroscopic and the measured values for all the stars is $0\rlap{.}''026$.

If the comparison is limited to the stars with several parallax measurements the systematic difference nearly disappears. Thus

TABLE III

Observer	No.	Δ
Miller..........................	34	−0″008
Mitchell........................	53	+0.003
Schlesinger.....................	15	+0.005
Slocum, Slocum and Mitchell, and Lee and Joy..................	36	+0.013
van Maanen......................	48	−0.006
Yale............................	148	+0.008

there are 59 stars in the list with parallaxes measured by three or more observers. The mean difference, spectroscopic *minus* measured values, for these stars is $+0\rlap{.}''001$.

A comparison with the measured parallaxes of various observers may also prove of interest. The results are given in Table III. Most of the Yerkes determinations are combined in one group.

COMPARISON OF SPECTRAL TYPES

Of the 500 stars in the list, 441 have spectral determinations by the Harvard observers. For the faintest of these stars only the even spectral class is given without subdivisions, or at most with divisions of five units such as G5 or K5. Accordingly the comparison is not altogether a fair one. The results are as follows, the unit being one-tenth of a spectral division, the interval, for example, from K0 to K1:

	Δ	Average Difference
Harvard–Mount Wilson estimates ..	−1.6	3.4
Harvard–Mount Wilson measures...	−0.7	3.2

These results are influenced greatly by a small number of large discrepancies, such as classifications of A and K for the same star in the two sets of observations.

A more valuable comparison is that of the brighter stars in the list. For these higher dispersion has been employed by the Harvard observers and the spectral division is given more closely. Using the values of the *American Ephemeris* we have in the case of 164 stars:

	Δ	Average Difference
Harvard–Mount Wilson estimates..	+0.5	1.6
Harvard–Mount Wilson measures...	+1.2	2.2

Although the number of stars used is much smaller in this case, the agreement is better than in the previous one. It is, of course, clear from the definition of the estimated and measured determinations of the Mount Wilson values that the estimates should be the more closely comparable with the Harvard results.

INTENSITY OF THE HYDROGEN LINES

The intensity of the hydrogen lines in stars of the same general type of spectrum must be recognized as furnishing valuable evidence as to the position of these stars in the system of stellar development.

The fact that the hydrogen lines are remarkably intense in the giant M stars and weak in the dwarf M stars was found some years ago in the course of classification work at this Observatory,[1] and a tendency in the same direction was recognized for some stars of the K type. Accordingly, in all recent classification work we have made two determinations of type. The first is based upon the general characteristics of the spectrum, such as the high-temperature and low-temperature lines, the intensity of the blue calcium line at λ 4227, the prominence of the bands, and many other features. For this purpose photographs of the spectra of stars typical of each type have been selected, and the spectrum to be classified is compared with these in turn. The second method of classification is based directly upon the intensities of the hydrogen lines and has been described fully elsewhere.[2] If therefore we compare the spectral types as derived by these two methods we obtain a measure of the intensities of the hydrogen lines. When the two determinations of type agree, the hydrogen lines are normal; when the measured value gives an earlier type, the hydrogen lines are exceptionally strong.

The comparison of the estimated spectral types of the stars in Table I with those derived from the hydrogen lines gives results of considerable interest. If we employ as the unit the same spectral subdivision as before, that is, the interval from K0 to K1, for example, and divide the stars into groups arranged according to spectral type and absolute magnitude we obtain Table IV. Under "Abs. Visual Mag." is given the arithmetical mean of the absolute magnitudes, and under "Est.−Meas." the difference in spectral type in the units referred to. Thus a value of +3.7 in this column means that the type from the hydrogen lines is 3.7 units earlier than the estimated value. If, for example, the estimated value were K8 the measured value would be K4.3.

It is probable that a difference of at least one unit in the two values for spectral type is due to accidental error or to a systematic deviation in the classification curves. The stars of low

[1] *Mt. Wilson Contr.*, No. 89; *Astrophysical Journal*, **40**, 385, 1914.

[2] *Mount Wilson Communications*, Nos. 23–26; *Proceedings of the National Academy of Sciences*, **2**, 143, 1916.

luminosity therefore show but little difference between the estimated and the measured values throughout all the spectral types, and the same is true for the high-luminosity stars of the earlier types. The hydrogen lines, accordingly, are normal for all of these stars. In the case of the high-luminosity stars, however, the intensity of the hydrogen lines is quite abnormal for the later K and more especially the M stars. There seems to be little doubt that this behavior is related to the well-recognized giant and dwarf division

TABLE IV

	No.	$M \leqq 3.9$		No.	$M \geqq 4.0$	
		Abs. Visual Mag.	Est. − Meas.		Abs. Visual Mag.	Est. − Meas.
F0–F4	28	2.8	− 0.7	10	4.7	−0.9
F5–F9	33	2.5	− 0.8	66	4.7	−0.6
G0–G4	14	1.6	+ 0.4	37	5.1	+0.7
G5–G9	63	0.8	+ 1.2	38	5.5	+1.7
K0–K3	58	1.2	+ 1.6	45	6.2	+1.2
K4–K9	21	1.3	+ 3.7	41	7.9	+1.0
M	30	1.2	+12.5	9	10.8	+0.4

of these stars, and that great intensity of the hydrogen lines is to be associated with high luminosity. They have accordingly been used as criteria for absolute magnitude in the case of the giant M stars.

THE GIANT AND DWARF DIVISIONS

The direct evidence bearing on the division into two classes afforded by the stars in this list may be most clearly indicated by a tabulation of the numbers of stars of the various absolute magnitudes. For this purpose narrow limits of magnitude should be selected. In Table V the results are given for an interval of 0.5 magnitude.

A graphical representation of these results is shown in Fig. 1. The clearly marked separation in the case of the M- and later K-type stars is seen persisting in the form of two strong maxima as far as those of the G type. The crests of these maxima draw more closely together in the successive types. There seem to be the rudiments of the first maximum among even the F stars, though

this is perhaps uncertain. The extraordinary grouping of the F stars around the magnitudes 3.0 to 5.5 is their most characteristic

TABLE V

Absolute Magnitudes	Ma–Md	K9–K4	K3–K0	G9–G0	F9–F0
− 3.0 to − 2.6	1	....	....	....	....
− 2.5 − 2.1	....	....	....	....	....
− 2.0 − 1.6	....	....	....	....	....
− 1.5 − 1.1	....	....	....	....	....
− 1.0 − 0.6	1	....	....	4	1
− 0.5 − 0.1	1	....	2	7	1
0.0 + 0.4	2	....	6	17	3
+ 0.5 + 0.9	6	6	13	19	4
+ 1.0 + 1.4	5	7	18	11	6
+ 1.5 + 1.9	8	7	10	5	3
+ 2.0 + 2.4	4	....	4	4	1
+ 2.5 + 2.9	1	1	1	3	7
+ 3.0 + 3.4	....	....	3	5	13
+ 3.5 + 3.9	1	....	1	2	23
+ 4.0 + 4.4	....	....	4	14	28
+ 4.5 + 4.9	....	....	1	12	26
+ 5.0 + 5.4	....	....	1	15	15
+ 5.5 + 5.9	....	1	6	15	6
+ 6.0 + 6.4	....	3	16	10	1
+ 6.5 + 6.9	....	6	8	3	....
+ 7.0 + 7.4	....	6	7	2	....
+ 7.5 + 7.9	....	4	2	1	....
+ 8.0 + 8.4	....	5	....	2	....
+ 8.5 + 8.9	....	8	....	1	....
+ 9.0 + 9.4	....	6	....	....	....
+ 9.5 + 9.9	2	2	....	....	....
+10.0 +10.4	3	2	....	....	....
+10.5 +10.9	4	....	....	....	....
+11.0 +11.4	2	....	....	....	....
+11.5 +11.9	....	....	....	....	....
+12.0 +12.4	....	....	....	....	....
+12.5 +12.9	....	....	....	....	....
+13.0 +13.4	1	....	....	....	....

feature. The absolute magnitudes of the maxima of frequency for the various types may be summarized as follows:

	Ma–Md	K9–K4	K3–K0	G9–G0	F9–F0
Giant....	+ 1.6	+1.4	+1.3	+0.6	(+1.1)
Dwarf....	+10.8	+7.8	+6.3	+5.3	+4.1

The question whether the selection of the stars observed may be accountable for the absence of stars of magnitude intermediate

between those of the two groups in the case of the M and K types should perhaps be discussed briefly. For the M stars it does

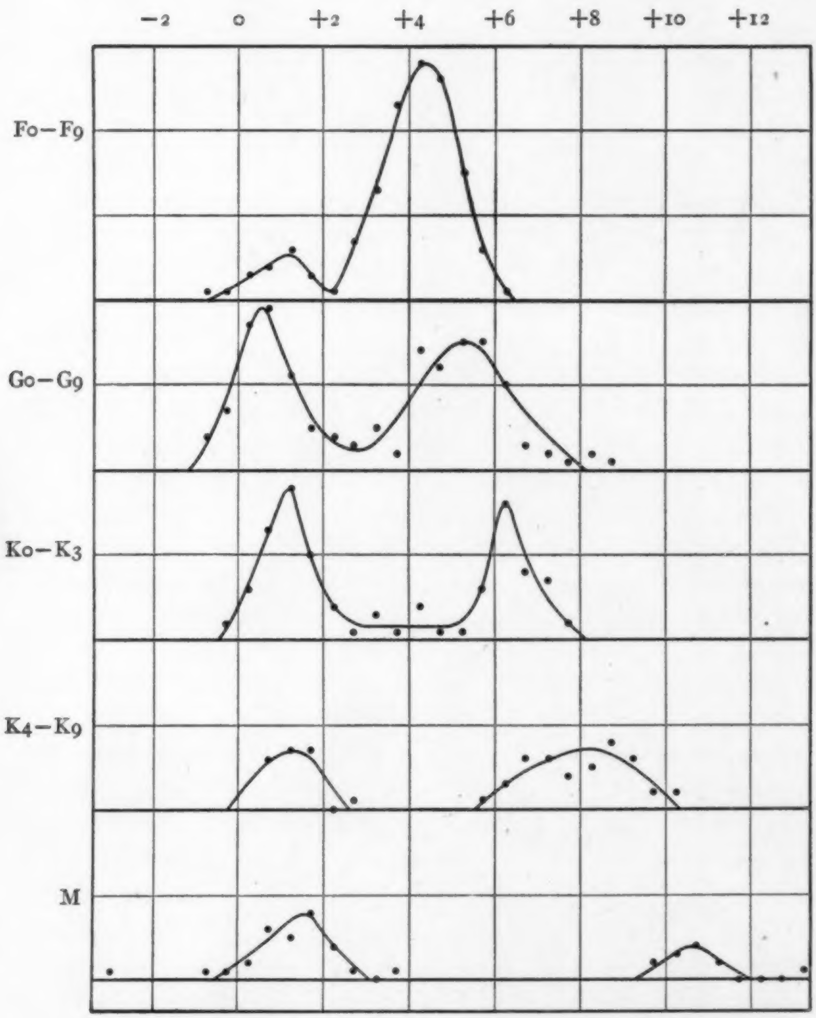


FIG. 1.—Frequency-curves of absolute magnitudes for different spectral types

not seem possible that this can be the case. Our observations have included all of the known faint stars of this type with large proper motions; about 15 stars with small proper motions and apparent

magnitudes between 7.5 and 8.5; and over one-third of the stars of this type listed in the catalogue of Boss with various proper motions. Throughout this list of about 110 stars the spectral differences between the two classes persist clearly, and there is no evidence whatsoever of an intermediate type of spectrum. The interval of over six magnitudes remains without representation.

The same argument applies, but in less degree, to the K-type stars. Among the great number of K stars given in Table I there is a wide variety in proper motion and apparent magnitude. It is difficult to see why this list, which contains representatives of both the giant and the dwarf classes, should not contain a full share of stars of intermediate absolute magnitudes, if such exist.

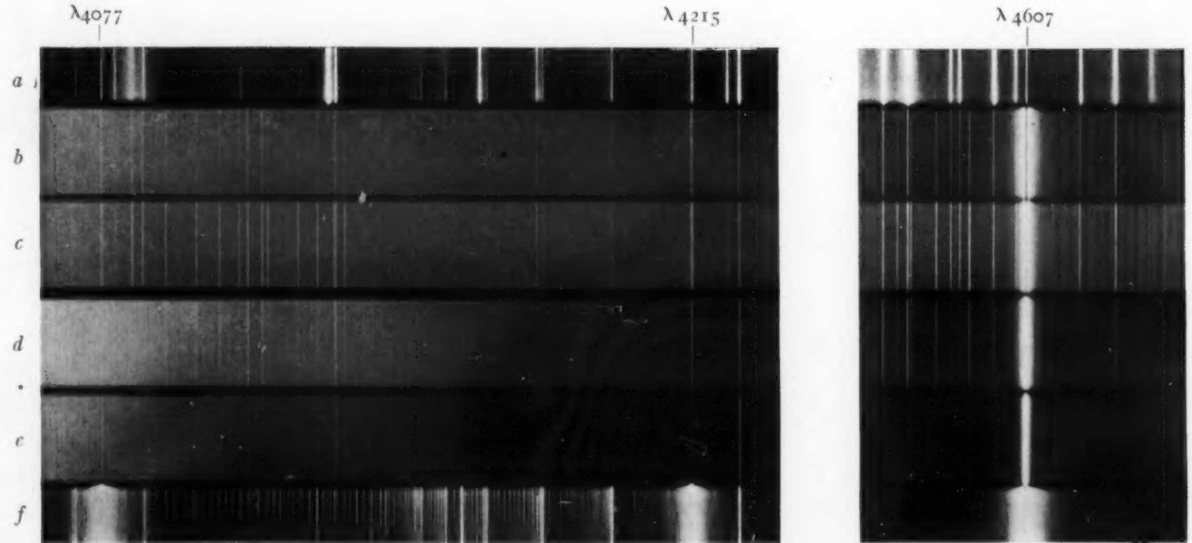
In the case of the G-type stars it is possible that the basis of selection of the material has affected the results somewhat. The fact that stars of very large proper motion and of very small proper motion have formed a considerable portion of the observing list would tend to give an excess of very bright and very faint stars. This may account in part, but probably not wholly, for the two maxima of the G-type stars shown in Fig. 1. The stars of the *American Ephemeris*, which have not been selected on the basis of proper motion, should tend to smooth out these maxima.

THE BEHAVIOR IN LABORATORY SOURCES OF THE LINES USED FOR ABSOLUTE MAGNITUDE

Three of the most important lines used in the determinations of magnitude are the strontium lines λ 4077, λ 4215, and λ 4607. The first two of these are well-known enhanced lines, being very strong in the spectrum of the electric spark, and, as Mr. King has shown, weak in low-temperature sources such as the electric furnace. The line λ 4607 is of the opposite type and is very strong in the furnace spectrum. A reproduction of photographs of these lines made by Mr. King is given in Plate XVII. The two lines λ 4077 and λ 4215 are identical in behavior in laboratory sources, and it is of interest to note that both are very prominent lines in the spectrum of the solar chromosphere.

The calcium line at λ 4455 is a well-known low-temperature line analogous in behavior to λ 4607 of strontium. The line at λ 4290

PLATE XVII



VARIATION WITH TEMPERATURE OF LINES IN FURNACE SPECTRUM OF STRONTIUM

a, Barium arc
b–e, Furnace spectra of strontium: *b*, 2350° C., high vapor-density; *c*, 2350° C., low vapor-density; *d*, 2000° C.; *e*, 1650° C.
f, Strontium arc

is a strongly enhanced titanium line and appears at an early stage in stellar spectra of type A.

Summarizing these results for all of the lines used we have the comparison given in Table VI.

It is probable that the line at λ 4207, like so many of the unidentified lines of Rowland's table, is enhanced. The hydrogen lines $H\gamma$ and $H\delta$ cannot well be classified according to laboratory behavior, although they certainly are not low-temperature lines. The intensity of the hydrogen lines in stellar spectra of types A and B points rather to the opposite conclusion.

TABLE VI

Line	El.	Spectral Types	High-Lumin. Stars	Low-Lumin. Stars	Cool Spark	Hot Furnace
4077..........	Sr	A8–F5	Strong	Weak	Strong	Weak
4215..........	Sr	A8–M	Strong	Weak	Strong	Weak
4290..........	Ti	A8–F5	Strong	Weak	Strong	Weak
4455..........	Ca	F6–M	Weak	Strong	Weak	Strong
4607..........	Sr	M	Weak	Strong	Weak	Strong
4207..........	....	M	Strong	Weak	Uhknown	Unknown
$H\delta$, $H\gamma$.......	H	M	Strong	Weak	....	....

The conclusion is obvious that the enhanced lines are relatively strong in the high-luminosity stars and the low-temperature lines strong in the fainter stars. That this is purely a temperature effect, however, is doubtful. The investigations of King with the electric furnace have shown the importance of the influence of vapor-density upon line-intensities, and we should expect wide variations in this respect in the atmospheres of different stars. The observed behavior may well be due to a combination of effects of both temperature and vapor-density in stellar atmospheres. The main consideration, however, is the direct evidence that the use of the absolute-magnitude lines has a definite physical basis and that the lines employed as criteria are as clearly distinguished by their behavior in laboratory sources as in stellar spectra.

GENERAL CRITERIA FOR ABSOLUTE MAGNITUDE

A study of the characteristics of the spectra of stars of very high and very low luminosity makes it clear that the variation of the

lines used as magnitude criteria forms but a portion of a much more general difference. This is most marked in the case of the M-type stars, but it is evident in other types as well. For stars of the same spectral type, the enhanced lines and the hydrogen lines are relatively strong in those of high luminosity and weak in those of low luminosity, while the low-temperature lines are relatively weak in the brighter stars and strong in the fainter stars. To illustrate we may take the case of two stars representing the giant and dwarf classes of M stars:

	α Orionis	Lal. 21185
Hydrogen lines	Very strong (G2)	Weak
Enhanced lines	Strong	Weak
λ 4227 of Ca	Weak	Very strong
Low-temperature lines of Ca, Sr, Fe, Ti, etc	Weak	Very strong

A very similar result, though somewhat less in degree, is found from a comparison of K-type stars of high and low luminosity. There is little question that λ 4227 of calcium is strongly dependent upon absolute magnitude, being very intense in the low-luminosity stars. We have as yet been unable to employ it satisfactorily, however, because of its great intensity and its rapid change with spectral type.

SUMMARY

1. The absolute magnitudes, luminosities, spectral types, and parallaxes of 500 stars have been determined from investigations of their spectra.

2. A comparison with the directly measured parallaxes of 360 of these stars shows the spectroscopic values to be about $+0\overset{''}{.}004$ larger in the mean. The average difference is $0\overset{''}{.}026$, if all parallaxes are included. A comparison with the 59 parallax values determined by three or more observers gives a difference of $+0\overset{''}{.}001$ in the mean.

3. A method of determining the absolute magnitudes of stars of types A8 to F5 has been derived, and improvements have been made in the methods used for the two classes of M-type stars.

4. A comparison of the determinations of spectral type with those made by the Harvard observers gives a difference of −1.6 spectral divisions in the mean, the Mount Wilson estimates being the later. A comparison for 164 stars listed in the *American Ephemeris* gives a difference of +0.5 division.

5. Abnormal intensity of the hydrogen lines is a characteristic of the highly luminous stars of the later types. This is almost certainly related to the giant and dwarf division among these stars.

6. A comparison of the number of stars of each absolute magnitude shows very clearly the giant and dwarf divisions for the M, K, and probably G types of spectrum, with a slight indication even in the case of the F stars. It is almost certain, in the case of the first two of these types at least, that these results cannot be ascribed to the selection of the stars.

7. The lines used for determinations of absolute magnitude are lines which in laboratory sources show marked variations with vapor-density and temperature. The lines which are strong in the highly luminous stars are strong in the electric spark; those strong in the fainter stars are strong in the electric furnace. The correspondence is complete.

8. The high-luminosity stars are characterized by spectra in which both the hydrogen lines and the enhanced lines are abnormally strong. In the spectra of the fainter stars all of the low-temperature lines are strong, including the blue line λ 4227 of calcium. The lines used for determinations of magnitude form but a part of this more general spectral distinction.

Mount Wilson Solar Observatory
September 1917

THE STRUCTURE OF THE MERCURY LINE, λ 2536

By LUCY WILSON

The structure of the line of the mercury arc of wave-length 2536.72 A is of special interest because of its remarkable efficiency in exciting "resonance."[1] For the investigation of the structure of this line, a Fabry and Perot interferometer was selected because of the high resolving power attainable with this instrument under proper conditions. The first part of the problem, therefore, consisted in the study of the relative reflecting power and transmission of various thin films in the region of the 2536 line, in order to find that substance which would be most efficient as a coating for the interferometer plates.

I. THE ULTRA-VIOLET INTERFEROMETER

Any interferometer of the Fabry and Perot type depends for its efficiency upon the number of reflections that it is possible to obtain in the region to be investigated, and upon their relative intensities. These two factors depend only upon the reflecting power of the surfaces, as may be seen from Fig. 1 and Table I.

Let *BC* and *DE* (Fig. 1) be the two plates of the interferometer upon which is incident a ray of light whose intensity is represented by 100 after it has traversed the first plate. Assume the reflecting power of the surface to be 30 per cent and the absorption to be zero, then the intensities of the images will be as represented. The first image I_1 is due to the transmitted light which has suffered only one reflection; the second image is produced after three reflections; the third, after five, and so on. The effect on the relative intensities of the images of increasing the reflecting power is apparent from the figures below, which were obtained by calculation from diagrams like Fig. 1.

It is at once evident that, as the reflecting power increases, the ratio of the intensities of the successive images approaches unity.

[1] R. W. Wood, *Philosophical Magazine* (6), **18**, 240, 1909; **23**, 689, 1912; **32**, 329, 1916.

Absorption cuts down the intensity of each transmitted image but does not affect the relative intensities of successive images.

If the reflecting power of the surfaces of the interferometer plates which face each other is f, the relation between the relative

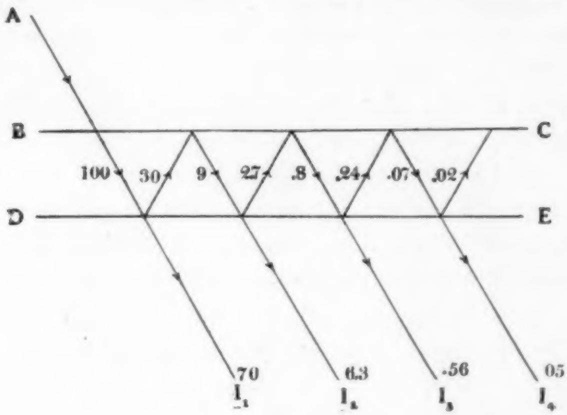


FIG. 1

intensities of the maxima and minima of the fringes produced is given by[1]

$$r=\left(\frac{1-f}{1+f}\right)^2 .$$

For example, a value of $f=74$ per cent gives a value of $r=0.02$; i.e., the minima are almost black. Thus the definition of the fringes depends entirely upon the reflecting power.

TABLE I

Reflecting Power	30 Per Cent	50 Per Cent	70 Per Cent	80 Per Cent	90 Per Cent
I_1	70.0	50.0	30.0	20.0	10.0
I_2	6.3	12.5	14.7	12.8	8.0
I_3	0.56	3.13	7.2	8.2	6.6
I_4	0.05	1.6	3.6	5.2	5.9

In using thin films, there are two ways in which the reflecting power can be increased: a thin film of a given substance can be made more highly reflecting by making it thicker up to a certain

[1] Fabry and Perot, *Annales de Chimie et de Physique*, **12**, 459, 1897.

limiting point, and a substance of naturally higher reflecting power can be substituted in place of the one under consideration.

Method.—The method of comparing various metals with respect to their efficiency for use in the Fabry and Perot ultra-violet interferometer was a very simple one. Thin films of the substance were deposited on the one-inch quartz plates of the interferometer, and the plates were mounted in the etalon with a wedge-shaped layer of air between them. This was accomplished by inserting a small piece of ordinary writing paper between the plates at a point near their edge, and by bringing the plates into contact at a point 180° removed from the paper, by means of the adjustment screws attached to the mounting of the etalon. Thus multiple images were obtained of any source of light viewed through the plates. The

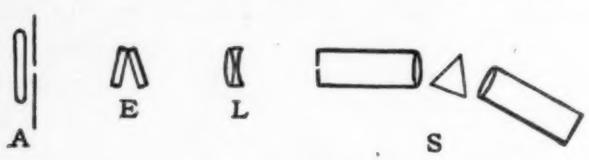


FIG. 2

images in the 2536 line were then photographed. The actual arrangement is represented in Fig. 2. The etalon E was mounted at about a meter's distance from the quartz water-cooled mercury arc A, in front of which was an aperture of 1 mm diameter. A quartz-fluorite achromatic lens L, at a distance of a meter from the etalon, brought the images to a focus on the slit of the quartz spectrograph. In the position of each line of the mercury spectrum, as viewed in the spectrometer and as recorded on the photographic plates, there appeared a series of vertically arranged dots of diminishing intensity. The number of images and the relative brightness of the successive ones were by this means immediately evident. With the films which showed up best by this method, photographs were also taken of the fringes formed when the plates were mounted in the etalon with separations of six and of 10 mm.

Up to this time, silver has been almost universally used in the visible region and nickel in the region of shorter wave-lengths for which the silver failed to give sufficient reflecting power. Cathodi-

cally deposited nickel was used by Fabry and Buisson in their investigation on "Wave-Length Measurements for the Establishment of a System of Spectroscopic Standards," published in the *Astrophysical Journal* of October 1908 (**27**, 169). Their observations extended as far as wave-length 2373. Other observers have also used nickel deposited by cathodic sputtering in the region of wave-lengths slightly longer than that of the 2536 line. The work of Dr. E. O. Hulburt in this laboratory on the "Reflecting Power of Metals in the Ultra-violet Region of the Spectrum"[1] showed that silicon possesses a much greater reflecting power in the regions between 2000 and 3000 A than does nickel. It was, therefore, hoped that silicon might be of use in the present case. Ultimately, films of nickel, silicon, cobalt, aluminum, platinum, silver, gold, and stibnite were prepared and examined.

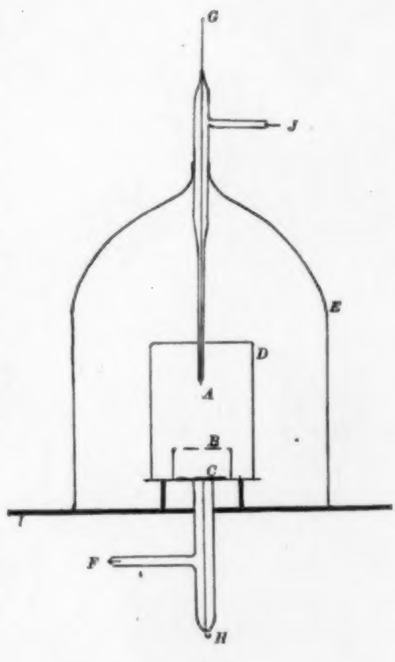


FIG. 3

As many of the films were sputtered cathodically with the same apparatus, a description of it (Fig. 3) in its general form is given here. The large bell-jar *E* was held air-tight against the ground glass plate *I* by means of stopcock grease. To avoid the presence of hydrocarbon vapor, the discharge was confined as nearly as possible to the interior of the inner vessel *D*. The cathode *C* consisted of a large flat piece of the metal to be sputtered (the area was of the order of 10 or 15 sq. cm) and the anode, *A*, was the pointed end of an aluminum rod. The lead wires of both electrodes were incased in glass to prevent the discharge from taking place outside *D*. The

[1] *Astrophysical Journal*, **42**, 205, 1915.

surfaces on which the film was to be deposited were mounted on a glass stand at *B* with their faces toward *C*. Connections to the pump were made through *F* and to the transformer by means of *G* and *H*. The transformer operated on the 110-volt alternating current and gave approximately 26,000 volts across the secondary. The pointed shape of the anode and the large flat cathode caused the rectification to take place always in this direction. A side tube *J* allowed any desired gas to be introduced into the vessel.

Silicon.—The silicon films obtained by cathodic sputtering in the atmosphere of mercury vapor yielded disappointing results in that their absorption for the ultra-violet was large. This was probably due to the presence of a trace of carbon from the stopcock grease, which not only made the films faintly brown in color but also caused them to adhere to the surface upon which they were deposited with such tenacity that they could be removed only by repolishing with rouge. Since it was desired to have not only an efficient ultra-violet interferometer but also one that could be easily prepared, the investigation was abandoned in favor of other substances. Later on, however, some beautifully bright silicon films were loaned to us by Mr. W. F. Meggers of the Bureau of Standards. These films were free from the brownish tint, and their absorption was only that which was to be expected from their thickness. Multiple images with them gave, however, a slightly less favorable ratio of intensities than that obtained from our best nickel films.

Nickel.—The nickel films tested were prepared in three different ways:

a) Films of varying thickness were deposited cathodically in an atmosphere of hydrogen and in air. The sputtering apparatus was arranged as represented in Fig. 3. The inflow of the hydrogen was so regulated that the dark space at the cathode was always maintained tangent to the surfaces of the plates upon which the nickel was being deposited. Good nickel films, i.e., those which are hard and gray and bright, were made in this way.

b) Nickel was distilled in a vacuum from a hot tungsten filament on to the quartz surfaces. A piece of fine tungsten wire was wound into a small spiral, and into this spiral was inserted a small sliver of nickel. *T* (Fig. 4) is the tungsten spiral whose lead

wires A and B connect with a 20-volt circuit containing variable resistance. The quartz plates are at Q and Q'.

In order to obtain films that were fairly hard the receiver was exhausted and the filament was given a preliminary heating before the quartz plates were introduced into the apparatus; this preliminary heating lasted until the nickel melted and a very thin deposit appeared on the walls of the vessel. After the plates were put in, the pump was allowed to run until the McLeod gauge indicated that most of the occluded gases had been given off. The current was then passed through the filament, and its strength increased until the filament reached a white heat. The films produced by this method were of much the same appearance as those deposited cathodically but were not as hard as the best cathodic ones. There was little difference in the behavior of the two sets of films.

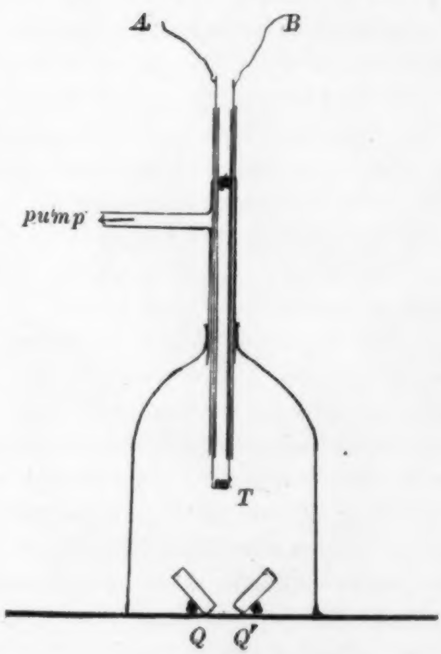


FIG. 4

c) A thin layer of nickel was electroplated from a solution of nickel fluorborate[1] on various foundations. For an initial layer, hard cathodic nickel was found to yield the best results. Nickel on gold and nickel on silver had a fair reflecting power but large absorption. The nickel distilled in vacuo was rather soft and inclined to frill as soon as the plate was removed from the electroplating solution. The films which gave the most favorable ratio of intensities in the multiple images and those which were finally

[1] A. Hollard, *Science Abstracts*, **15**, 558, 1912.

used in the work on the determination of the structure of the 2536 mercury line were made by electroplating upon a cathodic foundation. In order to insure hardness in the initial layer, the sputtering apparatus was arranged a little differently. The positions of the cathode and anode were interchanged, and the plates were covered with a piece of thin, sheet tin, and the discharge was allowed to run for two hours until its appearance indicated that little occluded gas was being given off. The tin was then removed by means of an electromagnet and the discharge continued for half an hour.

In the electroplating, the difficulty encountered was the production of a non-uniform layer owing to the greater density of the current near the surface of the liquid than at a short distance below it. This was in part compensated for by inclining the plate and in part by plunging the plate into the solution and slowly drawing it out, repeating the process several times until the film possessed the desired thickness.

This electroplated layer increased the reflecting power without increasing the relative absorption, i.e., a film made according to this last method possessed, with a given absorption, greater reflecting power than one of the same absorption made by either of the other two methods. These films were hard enough to permit polishing with rouge on a bit of cotton, but the process had little effect on the reflecting power.

Cobalt.—Cobalt of three different thicknesses was deposited cathodically in an atmosphere of hydrogen. The method was the same as that described under (*a*) for nickel. A thick film made by sputtering two and three-quarter hours showed good reflecting power but large absorption. A much thinner film, one made by running the discharge only thirty minutes, proved to be almost as efficient in the ultra-violet as the silicon and the electroplated nickel. A film of thickness intermediate between these two (i.e., one for which the sputtering lasted for one and one-half hours) gave less favorable relative intensities than the thin film. An interesting fact noted in connection with these cobalt films was that if a little moisture was deposited on them from the fingers (or elsewhere) the metal frilled and assumed the properties of matt surfaces.

Platinum.—This metal was sputtered cathodically in air and films of two different thicknesses were made and tested. The results showed them to be less desirable than the cobalt.

Aluminum.—From the work of Dr. Hulburt, mentioned above, it appears that as a reflector in the ultra-violet aluminum is second only to silicon. Like silicon, too, it is difficult to obtain in the form of a film. Experiments conducted by V. Kohlschütter and R. Miller[1] and by F. Fischer and O. Hähnel[2] on the "Kathodic Volatilization of Metals in Rarefied Gases" show that the presence of helium accelerates the volatilization of aluminum to a certain extent, and that argon greatly increases the rapidity of the process.

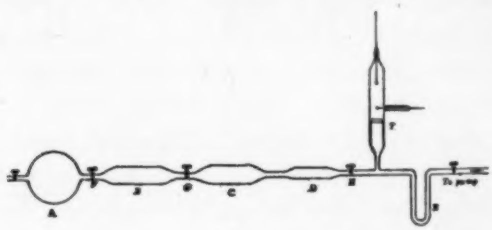


FIG. 5

Therefore the method used in this case was that of cathodic sputtering in argon. An entirely different form of apparatus from that previously described was made use of. It is represented in Fig. 5. The electrodes used in the discharge tube *T* consisted of small lumps of aluminum welded on German silver wire and placed at a distance of about 4 inches apart. The quartz plates (one at a time) were held in position an inch below the lower electrode. (Preliminary experiments with this distance, equal to 1 centimeter, showed decided non-uniformity in the deposit.) This tube was connected with a T-tube, one arm of which joined it to the pump through a U-tube immersed in liquid air and the other arm to the argon bulb *A* through a series of purifying agents. The bulb *B* contained calcium to remove the nitrogen; *C* contained cuprous oxide to remove the oxygen; and *D*, phosphorous pentoxide for absorbing water vapor. The secondary of an induction coil was connected to the electrodes.

[1] *Zeitschrift für Elektrochemie*, **12**, 365, 1906.

[2] *Ibid.*, **14**, 366, 1908.

The tube *T* was pumped out until the vacuum was such that the dark space was about 3 mm long. Until the final step in the procedure the connections from the induction coil were so made that the upper electrode was the cathode. The stopcocks *G* and *H* were open so that the tubes *B*, *C*, and *D* might be pumped out. When the pressure in *T* had reached its former value (as indicated by the appearance of the discharge), *G* and *H* were once more closed, and *F* opened for an instant to allow a small quantity of argon to flow into *B*. The tube *B* was then heated with a Bunsen burner until the calcium glowed. The stopcock *G* was next opened and the gas allowed to come in contact with the CuO which was also heated and with the P_2O_5. Upon opening the last stopcock *H* the gas flowed into the tube *T*, where it caused a marked change in the appearance of the discharge, due to the increase in pressure and to its characteristic spectrum. Observations with a direct-vision spectroscope showed that hydrogen was always present. This was, in all probability, given off by the aluminum electrodes. The tube was washed out with argon several times in the manner described above, the process lasting from half an hour to an hour. Then a heavy current was applied until the cathode (still the upper electrode) glowed to redness. When this condition was reached, the current was reversed until the lower electrode (now the cathode) reached red heat. The strength of the current in the primary was then reduced to half its former value and so maintained while the deposition took place. The deposit began suddenly, accompanied by marked changes in the appearance of the discharge. Before the cathode reached a temperature sufficient to cause it to glow, the predominating color of the discharge was a pale, whitish lavender; as the temperature of the cathode rose, the luminosity assumed a deeper violet hue; and just before the deposition began the color changed from this deep-blue violet to a bright rose color, which was very brilliant near the cathode, and shaded off to a pale violet in the region of the anode. Three minutes after this marked change took place the films were thick enough.

Though these films were brilliant in visible light and highly reflecting in the ultra-violet, experiments showed them to be slightly less efficient than the electroplated nickel.

Silver and gold.—Films of these two metals were sputtered cathodically in order to be able to make certain comparisons in the visible regions and to gauge some of the governing conditions from the various methods, and in the different forms of apparatus.

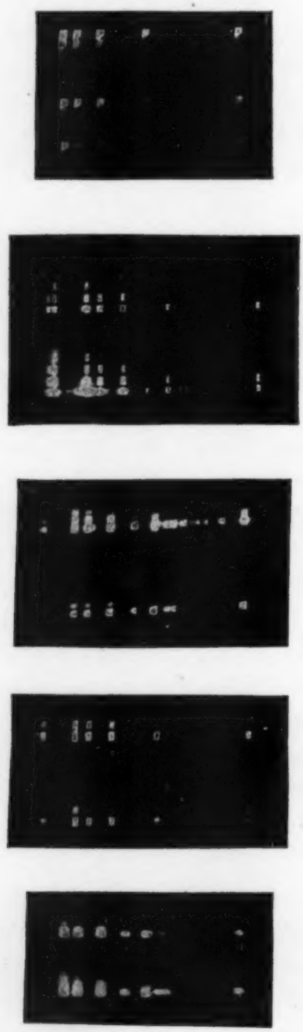
Stibnite.—Because of its remarkable optical properties it was thought that possibly this substance (sulphide of antimony) might prove of value. However, a film of stibnite obtained by cathodic deposit exhibited a very low reflecting power.

From a comparison of the photographs made with the various kinds of films and a consideration of the experimental difficulties involved in preparing the films, it was decided that nickel electroplated upon a cathodic foundation of nickel was best suited for the present investigation. The films used were, therefore, those described on page 345.

Every substance that offered any possibility of possessing high reflecting power in the ultra-violet was tried, but even the best films were most disappointing in the results which they yielded. The largest number of images ever photographed at the 2536 line was four, with the estimated intensity ratio given by a reflecting power of 40 per cent. In Fig. 6, a comparison of the images in the visible lines, photographed with silver films, with those obtained at the 2536 line with the best nickel films shows the relatively poor reflecting power of the latter in the ultra-violet region.

II. THE STRUCTURE OF THE 2536 MERCURY LINE

Method.—The method of using the Fabry and Perot interferometer in order to determine the difference in wave-length of two radiations situated very close together consists simply in finding the difference of path which corresponds to a position of "complete disagreement" or "dissonance" and of ascertaining whether this special path-difference represents the first time this condition has occurred as the plates are separated after being in contact. In the case of the Michelson interferometer, when dissonance occurs for a double line, the fringes disappear completely, if the lines are of equal intensity. In the Fabry and Perot interferometer, dissonance is indicated by a system of fringes with a spacing equal to one-half



Electroplated Nickel

Silicon

Cobalt

Aluminum

Silver

Fig. 6

of that which obtains for zero path-difference. As the path-difference is increased from zero position, the fringes first widen, then double, and finally form an equally spaced system of one-half the original interval.

With visible light, where the wave-lengths of the two radiations are widely different, one can easily watch the fringes get into step and out again, and the position in which one set of fringes is situated exactly between pairs of the other set can be estimated by the eye. For work in the ultra-violet it is, of course, necessary to make use of photography.

The same arrangement of apparatus was used as that indicated in Fig. 2, except that the interferometer was substituted for the etalon, and the screen removed from its position in front of the arc. The distance from the arc to the interferometer plates was about 60 cm, and the lens was placed a meter and a quarter from the interferometer plates. When the fringes were in focus on the slit of the spectrograph $LD = 51$ cm.

For this work, where it is necessary to have a variable path-distance the etalon was discarded and a mounting substituted by which the plate nearer the arc could be made to approach or recede from the other plate by steps as small as a hundredth of a millimeter. This was accomplished by means of a fixed screw with graduated head and a movable nut on which the one plate of the interferometer was mounted. It was found necessary to diaphragm the interferometer to an aperture of 9 mm because of non-uniformity in the films.

The first step in the procedure consisted in determining the position of contact of the plates. They were then separated by 1 mm and adjustments for parallelism were made for the visible region, i.e., either with a ground glass plate interposed between the arc and the interferometer or with a cell containing neodymium nitrate, which lets through only the green line. When the adjustments were completed, the absorbing screen was removed and the fringes photographed. The same process was repeated for each millimeter up to seventeen. The times of exposure varied from forty-five seconds to five minutes. An exposure of three minutes showed on the average the best contrast.

RESULTS

In the trial experiments with the etalon, the best films of several of the metals showed the fringes in the 2536 line double when the separation was 10 mm. The subsequent work with the electroplated nickel films showed that the fringes in this line were single at a separation of 9 mm and again at 13 mm, but for all intermediate points they were double, and the position of complete disagreement came at a separation of 11.7 mm. The region from zero path-difference up to this point was then examined in half-millimeter steps. No sign of doubling could be detected, and it was therefore concluded that 11.7 mm was the position of the *first* complete disagreement. Investigation was then continued beyond 13 mm up to 2 cm. The fringes gradually faded away into invisibility.

Hence the conclusion is that the line is a doublet, each component of which has a finite width. These results correspond to a Michelson visibility-curve of the form shown in Fig. 7.

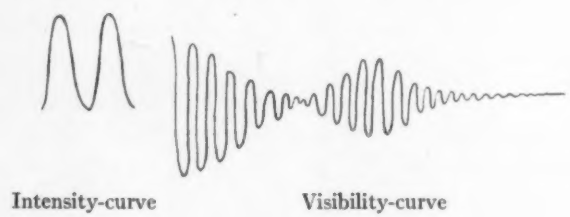


FIG. 7

The possibility of the foregoing intensity-curves being due to reversal instead of to a true double line was ruled out by the following experiments. Photographs which were made with a "mercury resonance bulb" duplicated the observations given by the arc. A mercury resonance bulb consists simply of a quartz bulb containing mercury vapor at room temperature, illuminated by light from a quartz mercury arc. Under these conditions the bulb emits a monochromatic radiation of wave-length 2536 which is designated as "resonance radiation." In this case, the mercury vapor present was less dense than in the arc. The water-cooled mercury arc, as it was always used, was flanked on either side by the coils of an electromagnet which deflected the arc forward on to the

quartz window in order to diminish the absorption effect as much as possible. For the purpose of the present experiments, the direction of the current in the magnet was reversed and long exposures (i.e., two to three hours) were made, with the result that no trace of the fringes and only a faint trace of the line itself was discernible. Therefore, a change in possible absorption does not change the intensity-curve, i.e., the relative intensities of the two components remain unaltered.

Calculations of the wave-lengths of the components.—Let the fringes of wave-lengths λ and $(\lambda+\alpha)$ be in position of complete disagreement and let $\Delta=$ the path-difference.

Then $\Delta=2e$, where e is the thickness of the air film between the plates.

If the order of interference is p, then the pth fringe of rays of wave-length $(\lambda+\alpha)$ lies in the center between the pth and the $(p+1)$th fringes of the rays of wave-length λ.

The pth fringe of the rays λ corresponds to a difference of path Δ and the pth fringe of the rays $(\lambda+\alpha)$ corresponds to the path-difference $\left(\Delta+\frac{\lambda}{2}\right)$. Therefore

$$p=\frac{\Delta}{\lambda}=\frac{\Delta+\frac{\lambda}{2}}{\lambda+\alpha}\,,$$

and

$$\frac{\alpha}{\lambda}=\frac{\lambda}{2\Delta}=\frac{1}{2p}\,.$$

Applying the results obtained from the experiments to this last equation gives

$$\frac{\alpha}{\lambda}=\frac{2536.72\times10^{-7}}{46.8}\,,$$

$$\alpha=\frac{(2536.72\times10^{-7})^2}{46.8}=14\times10^{-10}\,.$$

Therefore the results given by the Fabry and Perot interferometer lead to the conclusion that the 2536 mercury line is a doublet, the components of which are separated by 0.014 A. To determine

the probably more complicated structure of this line, an instrument of greater efficiency than the Fabry and Perot interferometer is necessary.

This problem was undertaken at the suggestion of Professor Wood, and the investigation was carried on under his direction. To him I wish to extend my thanks for his unfailing interest as well as for his invaluable help.

I wish to express my gratitude to Professor Ames, whose kindly interest has been continually manifest; and to Dr. Pfund and Dr. Anderson for many helpful suggestions; also to Mr. Meggers for making the silicon films.

Johns Hopkins University
June 1917

Minor Contributions and Notes

ON THE TEMPERATURE AND RADIATION OF THE SUN

Messrs. C. G. Abbot, F. E. Fowle, and L. B. Aldrich, in their article in this *Journal* (**44**, 39, 1916), criticize my paper published here in **43**, 197, 1916. They complain that I have not considered the scattering of light, due to which in the earth's atmosphere almost 10 per cent of the sun's light is scattered in all directions, and in the solar atmosphere perhaps even much more.

It is proper to remark that my equation

$$I_s = Ip^{F(s)}$$

results from a general differential equation for a ray of energy, i, passing through a medium of thickness, s,

$$di = -\nu i\, ds$$

giving by integration

$$i = Ie^{-\nu s}$$

independently of whether we consider the coefficient of transmission as expressing the effect of absorption with the constant ν,

$$p = e^{-\nu s},$$

or the effect of scattering with the constant κ,

$$p = e^{-\frac{\kappa}{\lambda^4}}.$$

Consequently I neglect, as do many others and these authors, in the earth's atmosphere only that part of the scattered light which enters into the direct solar beam from the atmosphere and reaches the observer; that is to say, I neglect the brightness of the earth's atmosphere with respect to the brightness of the sun; and in the solar atmosphere I neglect, as do many others, also only the brightness of the solar atmosphere with respect to the brightness of the photosphere. To what extent this first brightness is negligible with respect to the second can be determined from the black tone of the

nuclei of sun-spots or of the absorption lines in the solar spectrum, because it is the entire radiation of the solar atmosphere, augmented by the radiation of the photosphere transmitted by the absorbing layers, which is projected on the background of these spots or lines.

Let us recall the research by A. Schuster, referred to in the first part of my investigation,[1] where the author examines both the radiation of the photosphere and that of the solar atmosphere. The intensities of the radiation computed by him for the photosphere, as well as the temperatures deduced for it by me, are almost indistinguishable from the intensities and temperatures deduced from the same observed data without considering the radiation of the solar atmosphere.

That the supposition of a black radiation for the photosphere, transmitted by the solar atmosphere practically not radiating compared to the latter, was sufficiently well founded we see finally from the deduced distribution of energy in the spectrum of the solar photosphere, which agrees with the distribution in the spectrum of a black body of known temperature.

With regard to the criticism by these authors as to the relation noted by me between the deduced values for the solar constant and for the coefficients of transmission of the earth's atmosphere observed correspondingly, I reply as follows: The authors criticize my observational data, while they cite many analogous unfavorable atmospheric conditions to justify the uncertainty of their own observations. Moreover, it is notably these unfavorable atmospheric conditions which place more in relief the parallelism noted between the solar constants and the coefficients of transmission, not only in my observations at Warsaw and on Ararat, but also in all the observations by the authors at Washington, on Mount Wilson, and at Bassour. If no relation exists between these constants and coefficients, the probability of a parallel progression in time, direct or reciprocal, between them ought to be expressed by ± 0 per cent. However, this probability is expressed for Mount Wilson and Bassour equally by -27 per cent and -26 per cent (omitting one extreme value), thus showing that in these two places small solar constants correspond to large coefficients of transmission

[1] *Astronomische Nachrichten*, **183**, 241, 1910.

and vice versa. For the direct parallel progression between the coefficients of transmission on Mount Wilson and at Bassour a probability of +59 per cent results. For the parallel progression between the solar constants on Mount Wilson and at Bassour there results an equal probability, in sign and size, +58 per cent. It therefore follows that these deduced solar constants depend on observed coefficients of transmission of the earth's atmosphere, affected in their turn by the eruptions of Mount Katmai, because it is not possible that reciprocally the observed eruptions of Mount Katmai should be determined by the solar constants deduced at that time.

The authors of the paper, having chosen in Table I the days of observation without extreme atmospheric conditions, have without doubt diminished the clearness of the relation noted, as is seen in my observations on Mount Ararat as compared with those at Warsaw. Yet, for these data also, if they are construed as in my paper, they show a certain progression, less pronounced, but of the same sign, especially in 1910, 1913, and 1914.

I do not attempt to prove in my investigation that real variations in the radiation of the sun are not possible, but I testify only that it is very difficult to demonstrate it.

FELIX BISCOE

ROSTOV-ON-DON, RUSSIA
June 1917

WAVE-LENGTHS OF THE STRONGER LINES IN THE HELIUM SPECTRUM[1]

I. INTRODUCTION

For both practical and theoretical reasons the spectrum of helium is of considerable importance in spectroscopy and related branches of science. It consists of a comparatively small number of lines well distributed from the ultra-violet to the red, and is conveniently produced in great intensity in an ordinary vacuum tube. Hence it is widely used as a reference spectrum in spectroscopic and optical work of many kinds, but the wave-lengths

[1] *Scientific Papers of the Bureau of Standards*, No. 302; *Bulletin of the Bureau of Standards*, **14**, 159, 1917. By Paul W. Merrill, assistant physicist.

have not been known with sufficient accuracy for the most precise wave-length measurements. It is thought that the present determinations will supply this deficiency and make possible the use of helium lines as standards of wave-length. This investigation is a part of the standard wave-length program of the Bureau of Standards, which has been under way for two years and which is at present chiefly concerned with the spectra of iron, argon, and neon.

Helium is of great interest in astronomical observations, as it is one of the most important elements from a cosmic viewpoint, its spectral lines being prominently observed in such radically different objects as nebulae, early—that is, blue or white—stars, and the sun (flash spectrum).

As an aid to progress in the comprehension of the structure of matter nothing is of greater promise than an accumulation of accurate data in regard to spectral-line series. Thanks to the early investigations of Runge and Paschen, every line observed in the ordinary spectrum of helium may be placed in one of six series. In order to establish the mathematical form of these series and to throw light on their relations to one another as well as to the series of other elements, exact values of the wave-lengths of numerous lines will be required and will grow increasingly valuable as more data become available.

Precise measurements of the stronger helium lines were therefore undertaken in order that they may serve as standards for the determination of other wave-lengths, and to furnish a basis for computations of theoretical interest.

II. MEASUREMENT OF WAVE-LENGTHS

1. *Direct determinations from the red cadmium line.*—Wave-lengths of 21 of the stronger helium lines were measured with the Fabry and Perot type of interferometer, which consisted of two partially reflecting plane surfaces held a few millimeters apart and exactly parallel by an invar separator, using the practice previously adopted by the Bureau of Standards.[1] The interference rings formed by the action of the parallel planes of the interferometer

[1] *Bulletin of the Bureau of Standards*, **12**, 179, 1915; **13**, 245, 1916.

upon the incident light were projected upon the wide slit of a spectrograph having a single prism of rock salt, portions of them accordingly being observed as short bars across the spectral lines. The specially designed achromatic lenses allowed a great range of wave-lengths to be photographed with one exposure. Thus, 2945A and 5875A, (D_3), were obtained on one plate, as were also 3888A and 7281A.

The helium tube employed is similar in every way to the neon tube described by Meggers.[1] It was filled at the Bureau with helium obtained from a London firm. The electrical excitation was furnished by stepping up from commercial alternating current of 110 volts, 60 cycles, to about 10,000 volts (on open circuit). Primary currents from 0.5 to 1.75 a were used, causing from 3 to 11 ma through the tube. The dark space was from 1 to 2 mm in width.

Several of the helium wave-lengths were compared directly with the fundamental standard by photographing the cadmium and helium spectra simultaneously upon the same plate. The cadmium lamp, electrically heated to about 300° C., was in the optical axis of the spectrograph, while the beam of helium light was brought into the axis by reflection from a partially transparent surface through which the cadmium light passed. This surface was formed by a thin film of nickel which had been cathodically deposited upon a quartz disk. Two series of photographs were made in this way, in one case the interferometer films being of copper deposited on glass and in the other of nickel on quartz. The copper interferometers employed were of 5, 10, and 20 mm separation, the nickel of 5, 10, 15, and 20 mm. The plates (Seed 27) were sensitized to the less refrangible rays by treating them with a solution containing dicyanin, pinaverdol, and ammonia. Exposures were made ranging from 4 to 15 minutes and with varying amounts of current through the tube. The results are tabulated in Table I. The agreement of the two series is considered satisfactory except in the case of 7065A. No other reason, however, than accidental error of observation can be assigned for this difference.

[1] *Ibid.*, **12**, 202, 1915.

The very small corrections to reduce the wave-lengths to standard conditions (760 mm, 15° C.) were applied.

TABLE I

HELIUM WAVE-LENGTHS BY DIRECT COMPARISON WITH CD 6438.4696

Copper Films	Nickel Films	Adopted	Copper Films	Nickel Films	Adopted
3888.646	0.646	0.646	(5047.734)	....	....
....	(4026.190)	....	5875.616	0.618	0.617
4471.476	.478	.477	6678.148	.149	.149
4713.143	.143	.143	7065.186	.190	.188
4921.928	.929	.929	7281.350	0.348	0.349
5015.675	0.675	0.675			

2. *Relative measurements.*—The values in Table I served for the determination of other helium lines on photographs of the helium spectrum alone. In this series the nickel films and separations of 3, 5, 7.5, and 15 mm were used with exposures from 20 seconds to 1 hour. With the exception of the three red lines which were not observed in this series, the ratios of wave-lengths in Table I were satisfactorily confirmed, and are apparently accurate to 1 part in 4,000,000. The combined results of all the measurements made in this investigation appear in the first column of Table II.

From the number and internal agreement of the individual determinations it seems that an error larger than 0.003A is scarcely to be expected and that probably most of the errors are smaller than that amount. In the case of the double lines the value, of course, refers to the stronger component. The weaker component seems to have been practically without effect upon the measurements, since accordant values were obtained from a considerable range both of effective exposures and of orders of interference.

This may be illustrated by the values obtained for D_3. It was customary to put several exposures of varying length upon each plate. Determinations of the difference between overexposed and normal or weak images are hence available for several plates. In units of a thousandth of an angstrom they run 0, 0, +1, +1, −3, +4, −5, the last three depending on a poor measurement in each case. The systematic difference is not larger than the accidental error. The photographs of helium alone were taken upon Seed 27

emulsion (not stained), but the longest exposure on each plate (about an hour) shows D_3 faintly. The wave-lengths of this line from four of these underexposed images are practically in agreement with the other determinations, there being possibly a tendency toward a slightly higher value. For 5015A, a single line, the

TABLE II

COLLECTED HELIUM WAVE-LENGTHS (IN I. A.)

Bureau of Standards	Rayleigh		Eversheim	Runge and Paschen
	(a)	(b)		
2945.104	....	....	....	.106
3187.743	....	....	....	701
3613.641	....	....	....	641
3705.003	....	....	....	007
3819.606	....	....	....	605
3888.646	....	....	....	638
3964.727	....	....	....	727
4026.189	....	....	....	192
4120.812	....	....	....	821
4143.759	....	....	....	766
4387.928	....	....	....	934
4437.549	....	....	....	549
4471.477	(478)	480	493	475
4713.143	(171)	142	154	074
4921.929	925	928	922	919
5015.675	680	678	683	556
5047.736	....	....	....	641
5875.618	616	623	639	650
6678.149	144	147	151	14
7065.188	189	197	207	22
7281.349	....	....	....	53

difference, strong minus weak exposure, is 0.000 or ±0.001A in 11 cases out of 13. The agreement of different interferometers is shown for two lines by Table III, which refers entirely to the direct comparisons with cadmium. The figures in parentheses give the number of exposures upon which the value depends.

3. *Elimination of difference of phase-change.*—The dispersion of phase-change at reflection from the interferometer mirrors has been referred to as "one of the less agreeable features" of interference measurements. It is customary to find the amount of the differential effect for different wave-lengths by observations with large and small path-differences, and to compute the small corrections to be applied to the measured wave-lengths. This

procedure is, however, by no means necessary, as the whole effect can be eliminated by using differences, as was done by Priest[1] for visual methods. Let us find by the use of the standard line, say Cd 6438A, the double thickness of a large and of a small interferometer. If the difference of these numbers be divided by the difference of the measured orders of interference for another line, it is obvious that the quotient will be the correct wave-length

TABLE III

WAVE-LENGTHS FROM DIFFERENT INTERFEROMETERS

(Comparisons with cadmium)

	5015A		5875A	
	Copper	Nickel	Copper	Nickel
5 mm	0.674 (2)	0.677 (2)	0.617 (3)	0.619 (3)
10 mm	.673 (3)	.674 (2)	0.616 (3)	.617 (2)
15 mm	....	.675 (5)	....	.618 (6)
20 mm	0.677 (3)	0.676 (3)	....	0.618 (3)

freed from any effect of difference of phase-change without having found that quantity at all. The difference of the orders will be of about the same accuracy as the larger one, for while the percentage error of the smaller may be greater the actual numerical uncertainty is less.

The same final values should, of course, be arrived at whether the difference of phase-change is eliminated as suggested above or determined by the usual methods and the proper corrections applied. This is the case in the present series of measurements.

III. COMPARISON WITH PREVIOUS VALUES

The present measurements and those by Lord Rayleigh[2] are in quite good agreement, as shown by Table II. Columns 2 (*a*) and 2 (*b*) are separate series of which the second is to be given greater weight. Eversheim's values[3] are greater, but the differences are not uniform. Except for 3187A the grating values of

[1] *Bulletin of the Bureau of Standards*, **6**, 573, 1911.

[2] *Philosophical Magazine* (6), **15**, 548, 1908.

[3] *Zeitschrift für wissenschaftliche Photographie*, **8**, 148, 1909.

the shorter wave-lengths by Runge and Paschen[1] are in good accord with the interference results. The discrepancies among the longer wave-lengths are possibly due in some way to the fact that their measurements depend upon comparison lines in another order (second). This is the case for 4713, 4921, 5015, 5047, 5875, 5678, and 7065A. The mean arithmetic residual, Runge and Paschen minus Bureau of Standards, for these lines is 0.052A, as compared with 0.0065A for the remaining lines, for which the comparisons were in the first order. Omitting 3187A, the mean residual for 12 of the shorter lines is only 0.003A.

Using an interference method which depends upon observing the disappearance of the central ring,[2] Priest found the apparent wave-lengths of certain helium lines to vary with the amount of current through the tube. Variations of this kind were not observed by him for 5015A.[3] Mr. Priest has kindly given me the exact value obtained by him for this line as 5015.679A. This is the mean of several accordant measurements.

IV. SERIES RELATIONS

When our understanding of spectral series is complete, the magnitudes of certain physical quantities can probably be computed from a single series, and from relations between different series, and it may be in this connection that accurate measurements of wave-length will finally be of the most value. In the meantime they can be used to determine the applicability of the various types of formula which have been suggested, to test the so-called "combination principle," etc. For obvious reasons the present investigation includes only a small number of lines at or near the beginning of each series. These lines, although favorably situated for the purpose, will not by themselves give the best values of the series constants, particularly of the convergence frequency. Hence no extensive recomputations have been undertaken at this time, but it was thought of interest to see how closely a three-constant formula based upon three consecutive well-determined lines would represent the remainder of the series.

[1] *Astrophysical Journal*, **3**, 4, 1896.

[2] *Bulletin of the Bureau of Standards*, **6**, 573, 1911. [3] *Ibid.*, **8**, 1, 1911.

None of the series can be represented exactly by a formula of the type

$$n=A-B/m^2$$

where n is the reciprocal of the wave-length, m represents successive integers, A and B are constants. This equation, however, gives a fairly close representation of the two first subordinate series (5875A, 4471A, etc.; 6678A, 4921A, etc.). The constant B is about the same for both and approximately 0.2 per cent larger than in the Balmer series of hydrogen.

It is well known that the Kayser and Runge formula

$$n=A-B/m^2-C/m^3$$

will give a fair representation of the helium series. The lines for which $m=3$, 4, 5, in each of the six series have been measured in

TABLE IV

SERIES CONSTANTS

$$n(\text{vac})=A-\frac{B}{m^2}-\frac{C}{m^3}$$

	First Group			Second Group		
	Principal	First Subordinate	Second Subordinate	Principal	First Subordinate	Second Subordinate
	CONSTANTS COMPUTED FROM $m=3$, 4, 5, IN EACH SERIES					
A.....	38 469.22	29 225.53	29 147.13	32 030.82	27 176.66	27 154.51
B.....	110 501.7	109 845.2	102 963.4	109 518.3	109 783.2	107 878.3
C.....	13 027.4	152.7	96 030.4	−1 887.8	226.2	38 826.8
	OBSERVED *minus* COMPUTED (ANGSTROMS)					
M....	....	....	....	....	....	....
2....	−18.2	....	....	+124.3	....	....
3....	0	0	0	0	0	0
4....	0	0	0	0	0	0
5....	0	0	0	0	0	0
6....	+ 0.18	+0.021	−1.06	− 0.030	+0.013	−0.34
7....	+ .34	+ .047	−2.2	− .091	+ .036	−0.71
8....	+ .45	+ .078	−3.2	− .103	+ .022	−1.07
9....	+ .56	+ .096	−4.0	− .19	+ .068	−1.30
10....	....	+ .134	....	− .21	+ .069	−1.54
11....	....	....	....	− .23	+ .072	....
12....	....	....	....	....	+ .090	....

the present investigation. The constants *A*, *B*, *C*, as computed from these three lines, appear in Table IV, which also contains the residuals of all the well-observed lines in each series.

In every instance the error of the representation even for $m=6$ is very much larger than the uncertainty of observation, while the residuals show a fairly smooth and converging increase toward the terms of higher order. In some cases there is no improvement as compared with the series computed by Kayser and Runge from less accurate values. This is in agreement with the prevailing opinion that the formula contains the first three terms of a rapidly converging mathematical series which may be regarded as the expansion of a closed expression as yet unknown.

V. SUMMARY

Wave-lengths of 21 of the stronger helium lines have been accurately measured by interference methods. Nine of them were compared directly with the standard cadmium line.

The possibility of eliminating the effect of apparent variation of interferometer thickness with wave-length is noted.

The Kayser and Runge formula for spectral series, based upon three consecutive lines, will not reproduce accurately even the next member in any one of the six helium series.

PAUL W. MERRILL

WASHINGTON, D.C.
March 14, 1917

COMMUNICATION

Navy Department, U.S. Naval Observatory
Washington, D.C., November 16, 1917

To the Editor of the Astrophysical Journal:

Sir: The question has recently been raised in England whether the astronomical day should not be set back twelve hours, so as to begin at midnight instead of at noon. It is stated by those advocating the change that the practical consideration of those using the Nautical Almanacs should prevail as against the usage of astronomers. The opinion of American astronomers has been requested, and a committee of the American Astronomical Society has been appointed to collect information for presentation at the next meeting of the Society.

The Committee desires to obtain an expression of opinion on this subject from as large a number as possible of astronomers, geodesists, surveyors, navigators, and all others who have occasion to use Nautical Almanacs.

Communications may be sent direct to Professor W. S. Eichelberger, Director of the Nautical Almanac, U.S. Naval Observatory, Washington, D.C., or possibly better to some journal where a public expression of opinion may stir up further discussion.

Very sincerely,

W. S. Eichelberger
Chairman

[The editors are glad to bring the foregoing communication to the attention of the readers of this *Journal*, but suggest that any letters in reply be sent to some other periodical covering this field more closely, as, for instance, *Popular Astronomy*, Northfield, Minnesota.]

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